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Lower American River
EMIGRATION SURVEY
October 1997 - September 1998[1/][2/]

by

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SUMMARY

Rotary screw traps (RSTs) were used for the 5th consecutive year to acquire data on emigrating anadromous salmonids in the lower American River. Trapping was conducted near river mile (RM) 9 from 8 October 1997 through 30 September 1998.

A total of 194,819 chinook salmon emigrants was collected between 17 November 1997 and 31 July 1998. Four races of juvenile chinook salmon were collected (race determined by size-at-time criteria): 194,409 fall-run-sized salmon were collected between 17 December 1997 and 31 July 1998, 25 spring-run-sized chinook were collected between 23 January and 23 May 1998, 13 winter-run-sized chinook were collected from 10 December 1997 to 16 March 1998, and 372 late-fall-run-sized chinook were collected including one yearling-sized late-fall run collected on 17 November 1997, and 371 young-of-the-year (YOY) collected between 1 April and 8 May 1998. We also collected 115 YOY steelhead between 26 March and 12 August 1998 and 2 yearling steelhead, one in week 16 and one in week 21.

Chinook salmon emigrants were described by life stage as yolk-sac fry, fry, parr, silvery parr, and smolts. Most captured fall-run salmon were fry (79.0%), followed by yolk-sac fry (14.6%), parr (5.5%), silvery parr (0.8%), and smolts (<0.1%). Fall-run yolk-sac fry were collected between 17 December 1997 and 5 April 1998, fry between 17 December 1997 and 20 April 1998, parr between 26 January and 29 May 1998, silvery parr between 27 January and 31 July 1998, and smolts between 18 May and 25 June 1998.

Captured salmon yolk-sac fry lengths ranged from 25 to 39 mm fork length (FL), fry ranged from 25 to 65 mm FL, parr ranged from 25 to 89 mm FL, silvery parr ranged from 42 to 104 mm FL, and smolts ranged from 70 to 105 mm FL.

Fulton's condition factor (*K)* was determined for juvenile salmon $\geq$45 mm FL. Condition did not decrease on average as salmon smolted, although there was a decrease in maximum *K* with smolting. Overall, condition of salmon increased slightly as the fish developed in-river, whether expressed as a function of size (FL), life stage, or time. The salmon could be regarded as being in "good" individual condition with *K* typically averaging near or above unity.

Daily salmon catch peaked several times between mid January and late March. The daily peaks ranged from 4,500 to over 9,000 fish/day. The highest daily catch occurred on 7 March 1998, (week 10, 9,219 salmon). Mean weekly catches peaked twice, once in late January (week 5, 31,751 salmon) and once in early March (week 10, 34,525 salmon).

The total chinook salmon catch in 1998 (194,819) was the highest observed during the 5 survey years. A total of 32,064 salmon was caught in 1997, 45,478 in 1995, 132,040 in 1996, and 162,089 in 1994. Peak daily catch and overall catch rate were both lower in 1998 than those observed in 1994 and 1996, but substantially higher than those observed in 1995 and 1997.

Trapping efficiency was measured using mark-and-recapture techniques. The measured mean weekly efficiency in 1998 was the highest observed during the 5 sample years (1.09%).

Flow during the 1998 survey year was moderately high. Several high flow events [>10,000 cubic feet per second (cfs)] occurred during the survey period, beginning in mid January 1998. The highest flow event occurred during early February (>34,000 cfs). Flow reached or surpassed 10,000 cfs in the succeeding months until it eventually declined in early July. Flow then remained at about 4,000 cfs through September 1998.

Comparisons between mean and maximum January flows, and an index of survival to emigration (expanded number of emigrants/escapement) for all 5 survey years, indicates that survival may be inversely related to January flow conditions ($r = -0.766$). The survival index (i.e., the estimated number of fall-run emigrants/estimated number of fall-run spawners) in 1998 was 405 based upon an estimated emigration population of 18.9 million juvenile fall-run chinook salmon and an estimated spawner escapement of ~47,000.

INTRODUCTION

Anadromous fish emigration was monitored on the lower American River, Sacramento County, California (Fig. 1) from October 1997 through September 1998. This was the 5^{th}, consecutive year that emigration was monitored on the lower American River as part of a multi-year effort to evaluate flow and other habitat requirements of anadromous salmonids (Snider and Titus 1995, Snider et al. 1997, Snider et al. 1998, Snider and Titus 2000).

The timing and life-stage composition of emigrating salmonids can directly affect cohort survival and chronic changes in emigration can ultimately affect population persistence (Park 1969). Various abiotic conditions, many induced by human activities, are known to directly or indirectly alter emigration. Flow change (increases and decreases), flow magnitude, water temperature, turbidity, and habitat availability are some conditions that may be altered and affect emigration.

Fall-run chinook salmon *Oncorhynchus tshawytscha* emigration from the lower American River is vulnerable to all such conditions potentially resulting from flow regulation at Folsom Dam. An important objective of our investigations into flow-habitat relationships on the lower American River, is to identify relationships between timing, magnitude, and composition of emigrating chinook salmon and flow, temperature, and other factors potentially controlled by operation of the Folsom Project.

Since emigration can be influenced by anthropogenic disturbances in environmental conditions, it is essential that the relationships between such conditions and emigration, and ultimately survival to spawning, be understood if management of altered systems is to accommodate both short- and long-term survival of salmon and steelhead populations. Evaluation of the emigrating population can also relate production and survival of chinook salmon to precedent conditions of spawning, incubation, and rearing. As such, monitoring salmon emigration in the lower American River has been part of an investigation of the influences of altered flow on chinook salmon habitat requirements.

Our investigation has several objectives. The primary objective is to identify the general attributes of emigration on the lower American River, including timing, abundance, fish size, life stage composition, and fish condition, and to relate these attributes to primarily flow dependent, environmental conditions. We aim to develop an empirically-based model to link emigration with flow through repetitive investigations during years with varying chinook salmon population sizes and/or environmental conditions. Additionally, we plan to develop procedures to quantify or index the size of the emigrating population. Ultimately, we propose to associate production and survival with environmental conditions by combining emigration data with information being collected on spawner population size, numbers and distribution of redds, and the dynamics of the rearing phase of chinook salmon precedent to emigration.

METHODS

Anadromous fishes using the American River are restricted to the lowermost 23 miles, from Nimbus Dam to the Sacramento River (Fig. 1). Flow in this reach is regulated by Folsom Dam, which is operated by the U.S. Bureau of Reclamation (USBR) to provide water supplies, flood protection, hydroelectric power production, and to maintain fish and wildlife habitats. Flow during the migration period can range from less than 1,000 cubic feet per second (cfs) to more than 100,000 cfs. Large amounts of debris typically accompany flow changes as increased stage picks up debris along the river margins. Urban runoff from several flood control drains also introduces a variety of debris into the river.

Emigrating salmonids were sampled using two, 8-ft diameter rotary screw traps (RSTs). The traps were located immediately downstream of the Watt Avenue bridge (Fig. 1) on the north side of a large, mid-channel bar (Fig. 2). The same location was sampled during the previous 4 survey years. Sampling during the 1998 survey period extended from 8 October 1997 through 30 September 1998. Two traps were fished through 1 June 1998. One trap was fished from June through September. Sampling was essentially continuous, with only two, short interruptions: one during week 6 (1–7 February 1998), and one during week12 (15–21 March 1998). Both interruptions were associated with increased flow and accompanying debris buildup. Flow increased to over 34,000 cfs during week 6, resulting in stoppage of both traps for nearly 2 days. In week 12, flow increased to over 10,000 cfs; one trap was stopped for 1 day due to debris buildup.

The RSTs were serviced at varying intervals depending upon the density of migrating salmonids and the potential for debris buildup. The RSTs were serviced two to three times a week from October through late December 1997. The traps were serviced at least every weekday and sometimes on weekends from late December 1997 through mid January1998, and then every day from mid January through late April, except as noted above. Trap servicing during the last 5 months was conducted two to three times a week.

During each servicing, fish were removed from the trap, sorted, and counted by species (and race for chinook salmon[1/]). All captured steelhead, and all salmon appearing to be outside the fall-run size criteria for the time of capture, were measured [fork length (FL) to the nearest 0.5 mm, and weight to the nearest 0.1 g]. When the catch of fall-run-sized salmon was high (>300 fish), a subsample of 300 fish was measured comprising100 salmon taken at the beginning of the count, 100 taken midway through the count, and 100 taken at the end of the count. All measured salmonids were visually classified as yolk-sac fry, fry, parr, silvery parr, or smolts. Yolk-sac fry were defined as newly-emerged fish with a visible yolk sack ("unzipped"). Fry were defined as recently-emerged fish with a fully absorbed yolk sac ("zipped-up") and undeveloped pigmentation. Parr were defined as darkly pigmented fish with characteristic dark, oval-to-round

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1/ Chinook salmon race was determined using the size-at-time criteria developed by Frank Fisher, California Department of Fish and Game, Inland Fisheries Division.

parr marks, no silvery coloration, and firmly set scales. Silvery parr were defined as fish having faded parr marks and a sufficient accumulation of purine to produce a silvery, but not fully smolted, appearance. Salmon lacking or having highly faded parr marks, a bright silver or nearly white color, a pronounced fusiform body shape, and deciduous scales were classified as smolts. If all captured fish were not classified or measured, the total weekly catch was expanded for each life stage by multiplying the weekly percentage of each life stage by the weekly count.

Fulton's condition factor (*K*) was calculated for all salmon and steelhead $\geq$45 mm FL as 10^5(weight, g)/(FL, mm)^3. As well as determining general nutritional status, we assessed *K* as a function of FL to assess whether condition decreased as salmon grew to the smolt stage, a common diagnostic in smolting salmonids (Folmar and Dickhoff 1980; Wedemeyer et al. 1980).

Flow data were obtained from USBR release records for Nimbus Dam. The City of Sacramento provided turbidity data (Nephelometric Turbidity Units, NTUs) from measurements taken at the Fairbairn Water Treatment Plant at RM 7. Water temperature was continuously measured at the trap site throughout the survey period at two-hour intervals using an Onset Stowaway thermograph affixed to the RST. Water transparency (Secchi depth), water and air temperatures, and trapping effort (hours fished since last service) were measured and recorded at each servicing.

Between 5 January 1998 (week 2) and 1 June 1998 (week 23), all captured salmon and steelhead were marked, using Bismarck Brown Y stain (Deacon 1961), then released approximately 3,000 ft upstream of the trap. Marked fish were released from Saturday through Wednesday of each week. Recaptured fish caught between Sunday and Saturday were considered to have been released during the same week of capture. (The lag time between release and recapture observed during previous survey years, showed that essentially 100% of all recaptured fish are collected within 4 days of release). The percentage of marked fish recaptured during the week provided a measure of trap efficiency.

An estimate of the total number of salmon emigrating past the trap site was made by dividing the expanded catch (to account for the weeks when trapping was less than 100%) by mean trap efficiency. Weekly catches were expanded by multiplying the total number of potential trap hours for the week (e.g., 336 h per week for two traps) by the corresponding, weekly catch rate. The mean trap efficiency was calculated as the mean of all measured trap efficiencies when the number of marked fish was $\geq$100 salmon.

RESULTS

General

Flow was moderately high during the 1998 survey period (Fig. 3). Initially, flow was maintained near 2,400 cfs for most of October 1997 until the first high flow event which occurred when flow peaked above 14,000 cfs on 18 January 1998. A second high flow event occurred during early February when flow peaked above 34,000 cfs on 3 February 1998. High flow events subsequently occurred in late March (12,000 cfs) and throughout most of May (Fig. 3). Flow was well above 5,000 cfs during most of this period (February through June) and remained near 4,000 cfs from July through September

Mean daily water temperatures were relatively warm during the early part of the season (October–December), but were cooler during the latter, typically warm part of the season (April–September) (Fig. 3). Mean daily temperature gradually decreased from 66 °F in October 1997 to a low of 49 °F in late December 1997, then remained below 50 °F into mid April 1998. Temperatures increased to above 50 °F in mid April, but did not reach 56 °F until mid June and only exceeded 62 °F for a short period in mid August. Mean daily temperatures never rose above 65 °F.

Measured turbidity averaged less than 5 NTUs during the survey period, and peaked at 25 NTUs during the first high flow event in early January (Fig. 4). (Unfortunately, turbidity was not measured during the period of highest flow, mid January through late March). In comparison, turbidity was relatively high in the 1997 survey period, surpassing 600 NTUs, but rarely exceeded 10 NTUs during the 1994, 1995 and 1996 survey periods.

Twenty-one fish species were collected (Table 1). Juvenile chinook salmon accounted for the majority of captured fish (n = 194,819), followed by Pacific lamprey (n = 432), sculpin (n = 412), Sacramento pike minnow (n = 364), Japanese smelt (n = 133), and steelhead (n = 117).

Fall-run-sized Chinook Salmon

Fall-run chinook salmon emigration spanned 33 weeks, from 17 December 1997 (week 51 of 1997) through 31 July 1998 (week 31 of 1998) (Table 2). A total of 194,409 fall-run chinook salmon was caught in 8,901 hours of fishing effort (mean = 21.8 fish/h). Daily catch peaked several times between mid January and late March (Fig. 5). Peaks in daily catch ranged from more than 4,500 to more than 9,200 salmon/day. The highest daily catch occurred on 7 March 1998 during week 10, (9,219 fish, 396 fish/h) (Figs. 5 and 6), about 1 week later than the week when peak catches were observed in 1994, 1995 and 1997, but approximately 5 weeks later than in 1996 (Snider and Titus 1995; Snider et al. 1997, Snider et al. 1998, Snider and Titus 2000). The highest weekly catch (34,525 fish, 102 fish/h) also occurred in week 10 (1–8 March 1998). The second greatest weekly catch occurred in week 5 and was just slightly less than that observed during week 10 (31,751 fish, 96 fish/h) (Table 2, Figs. 7 and 8).

Table 1. Summary of fish species collected during the lower American River emigration survey, October 1996 through September1997. The species are listed in alphabetical order, by common name.

	1997			1998									
Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
American shad	36	17	0	0	0	0	0	0	0	0	2	0	55
Bullhead	0	0	0	0	0	0	0	0	0	0	0	0	0
Bluegill	21	28	0	0	0	0	2	5	3	0	0	0	59
Chinook salmon[1/] (fall run)	0	0	183	53,296	76,592	61,697	1,050	1,479	110	2	0	0	194,409
Chinook salmon[1/] (spring run)	0	0	0	0	1	7	11	6	0	0	0	0	25
Chinook salmon[1/] (winter run)	0	0	1	8	1	3	0	0	0	0	0	0	13
Chinook salmon[1/] (late-fall run)	0	1	0	0	0	0	370	1	0	0	0	0	372
Carp	1	0	0	0	0	2	0	1	2	0	0	1	7
Gambusia	1	0	1	6	4	0	0	0	0	0	1	0	13
Golden shiner	0	0	0	0	0	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	1	0	0	2	0	0	0	0	3
Hardhead	0	0	0	0	0	0	0	0	0	0	0	0	0
Japanese smelt	0	0	7	14	41	37	23	6	2	2	0	1	133
Lamprey (ammocoete)	0	8	19	47	1	44	33	34	12	5	3	6	212
Lamprey (subadult)	1	21	61	14	4	2	7	20	6	0	2	0	138
Lamprey (adult)	0	0	0	43	0	4	20	13	1	1	0	0	82
Largemouth bass	2	0	2	0	0	2	2	1	0	0	0	0	9
Mississippi silverside	4	8	1	0	1	0	0	0	0	0	0	0	14

Table 1 (cont.)

	1997			1998									
Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Redear sunfish	7	2	0	0	0	1	0	0	0	0	0	0	10
Sculpin	2	0	14	14	358	17	6	0	0	0	1	0	412
Smallmouth bass	0	0	0	0	0	0	0	1	0	0	0	0	1
Splittail	0	0	0	0	24	0	0	0	0	0	0	0	24
Sacramento pike minnow	13	25	31	38	12	73	103	55	4	3	4	3	364
Steehead (YOY)	0	0	0	0	0	4	23	75	9	2	2	0	115
Steelhead (yearling)	0	0	0	0	0	0	1	1	0	0	0	0	2
Striped bass	0	0	0	0	0	0	0	1	2	1	0	2	6
Sucker	0	5	7	4	0	0	1	4	0	3	5	5	34
Threadfin shad	9	0	3	2	11	1	1	5	0	0	0	0	32
Tule perch	6	1	33	38	1	2	1	1	1	0	1	6	91
Warmouth	1	0	0	0	0	0	0	0	0	0	0	0	1
White catfish	0	0	0	0	0	0	0	0	0	0	0	0	0

1/ Chinook salmon race based upon size criteria (F. Fisher, CA Department of Fish and Game).

Table 2. Weekly catch statistics for juvenile fall-run chinook salmon caught during the 1998 lower American River emigration survey, October 1997 through September1998.

Week	Beginning date	Hours fished	Total catch	Catch/h	Size statistics (FL in mm)			
					Mean	Min	Max	SD
No salmon were caught between week 40 and week 50								
51	14 Dec 1997	333	6	0.0	33.0	32	34	0.6
52	21 Dec 1997	339	30	0.1	28.0	37	32	1.9
1	28 Dec 1997	331	207	0.6	32.4	27	38	1.9
2	4 Jan 1998	337	1761	5.2	33.5	25	38	1.5
3	11 Jan 1998	384	4,257	11.1	33.9	28	39	1.5
4	18 Jan 1998	326	15,467	47.4	34.3	28	39	1.6
5	25 Jan 1998	330	31,751	96.1	35.1	29	46	1.6
6	1 Feb 1998	239	16,328	68.2	34.5	28	40	1.6
7	8 Feb 1998	335	18,193	54.4	34.8	27	46	1.8
8	15 Feb 1998	306	20,603	67.4	35.0	28	52	1.8
9	22 Feb 1998	335	21,468	64.1	35.1	29	58	1.8
10	1 Mar 1998	336	34,525	102.7	35.1	28	53	1.8
11	8 Mar 1998	336	18,211	54.2	35.3	29	61	2.3
12	15 Mar 1998	250	7,559	30.3	37.4	25	65	6.8
13	22 Mar 1998	378	1,182	3.1	36.0	25	65	5.0
14	29 Mar 1998	333	480	1.4	35.8	31	73	4.7
15	5 Apr 1998	313	220	0.7	38.7	34	74	8.1
16	12 Apr 1998	337	248	0.7	49.0	36	80	11.4
17	19 Apr 1998	284	273	1.0	60.0	37	81	9.0
18	26 Apr 1998	332	61	0.2	64.4	45	87	9.8
19	3 May 1998	330	119	0.4	71.4	54	93	8.2
20	10 May 1998	333	471	1.4	69.6	50	96	7.0
21	17 May 1998	336	535	1.6	74.9	53	95	6.9
22	24 May 1998	337	342	1.0	76.4	55	100	7.0
23	31 May 1998	240	65	0.3	82.0	66	105	7.0
24	7 Jun 1998	147	4	0.0	81.5	68	90	10.3
25	14 Jun 1998	165	27	0.2	86.5	70	102	6.3
26	21 Jun 1998	167	14	0.1	88.1	70	99	8.7
29	12 Jul 1998	167	1	0.0	-	-	-	-
31	26 Jul 1998	192	1	0.0	84.0	84	84	0
Total		8,901	194,409	21.8	38.0	25	105	10.6

No fish caught during weeks 27–28, 30, and 32–40 of 1998.

Fall-run salmon were caught each week beginning 17 December 1997 (week 51 of 1997) through 31 July 1998 (week 31 of 1998), except in weeks 27, 28 and 30 (Fig. 7). The catch-rate increased from <0.1 fish/h in week 51 (of 1997) to nearly 100 fish/h in week 5. Catch rate maintained above 50 fish/h until week 10 when it peaked at 102 fish/h (Fig. 8). After week 10, catch-rate decreased rapidly to only 3 fish/h in week 13, and then to generally less than 1.5 fish/h through the end of July (Table 2, Fig. 8).

Fall-run chinook salmon length ranged from 25 to 105 mm FL (Table 2). Mean weekly length ranged from 28 mm FL (week 52 of 1997) to 88 mm FL (week 26) (Table 2, Fig. 9). Between week 51 of 1997 and week 19 of 1998, nearly all salmon caught (>99% of the catch) were recently-emerged-sized fish (≤45 mm FL)[2] (Figs. 9 and 10). Between 17 December 1997 (week 51) and 12 April 1997 (week 15) mean length increased very gradually from 33.0 mm to 38.7 mm (Table 2, Figs. 9 and 10). Mean length then increased from 49.0 mm FL in week 16 to 60.0 mm FL in week 17 and then remained near 70 mm FL for 5 weeks, before increasing to over 80 mm FL through week 31.

The length frequency distribution for all fall run exhibited two size groupings (Fig. 11). The first group ranged from 25 mm to about 50 mm FL, (mode = 35 mm FL). This group contained the majority of salmon caught. The second group ranged from about 50 mm to 70 mm FL (mode = 70 mm FL).

Life Stage Distribution

The fall-run chinook salmon catch comprised 14.6% yolk-sac fry, 79.0% fry, 5.5% parr, 0.8% silvery parr, and <0.1% smolt (Table 3). Life stage composition in 1998 was similar to those observed in 1994, 1995, and 1996, but differed substantially from that observed in 1997 (Table 4). Notably, the proportion of parr caught in 1997 (47.7%) was much greater than in any other survey year. Similarly, the proportion of yolk-sac fry and fry was lower in 1997 than during the other 4 survey years. The combined proportion of yolk-sac fry and fry was 48.3% in 1997 compared to 96.7% in 1994, 93.6% in 1998, and about 73% in both 1995 and 1996 (Table 4).

Fall-run yolk-sac fry were caught during every week from 17 December 1997 (week 51) to 18 April 1998 (week 16) (Table 3, Figs. 12 and 13). The peak yolk-sac fry catch occurred in week 4 = 7,235) (Fig. 13). Yolk-sac fry lengths were fairly uniform (Figs. 13 and 14). Lengths ranged from 25 to 39 mm FL (mean =33.5 mm FL, SD = 1.64); 95% of yolk-sac fry were between 31

2/ The size classification identifies recently emerged-sized salmon as being late-fall-run beginning 1 April. To maintain consistency with the race classification system, all recently emerged salmon collected after 1 April were designated as late-fall run, although the change in race designation appears to be an artificial break in a continuum of salmon emergence that lasted through 8 May 1998 (week 19).

Table 3. Weekly life stage distribution of fall-run chinook salmon caught during the 1998 lower American River emigration survey, October 1997 through September1998.

Week	Yolk-sac fry	Fry	Parr	Silvery parr	Smolt	Total
51	4	2				6
52	29	1				30
1	165	42				207
2	1,206	555				1,761
3	2,434	1,823				4,257
4	7,235	8,232				15,467
5	7,054	24,021	674	1		31,751
6	3,017	13,311	0	0		16,328
7	2,769	15,023	393	9		18,193
8	1,835	17,901	868	0		20,603
9	994	19,184	1,230	59		21,468
10	1,101	31,658	1,737	28		34,525
11	420	15,632	2,152	8		18,211
12	98	5,164	2,287	9		7,559
13	21	809	342	10		1,182
14	5	313	159	3		480
15	0	110	102	8		220
16	2	8	169	69		248
17	0	1	244	28		273
18	0	0	52	9		61
19	0	0	103	16		119
20	0	0	101	370		471
21	0	0	30	489	16	535
22	0	0	2	323	18	342
23	0	0	0	59	6	65
24	0	0	0	4	0	4
25	0	0	0	26	2	27
26	0	0	0	2	12	14
29	0	0	0	0	0	1
31	0	0	0	1	0	1
Total	28,389 (14.6%)	153,790 (79.0%)	10,645 (5.5%)	1,531 (0.8%)	54 (<0.1%)	194,409 (100.0%)

Table 4. Comparisons of life stage composition of chinook salmon captured during emigration surveys made on the lower American River between 1994 and 1998.

Life stage	1994	1995	1996	1997	1998
Yolk-sac fry	96.7%	3.5%	22.6%	12.5%	14.6%
Fry		70.5%	59.6%	35.8%	79.0%
Parr	1.6%	25.5%	17.4%	47.7%	5.5%
Silvery parr	1.4%	0.1%	4.0%	3.9%	0.8%
Smolt	0.3%	0.4%	0.00%	<.01%	<.01%

mm and 37 mm FL (Fig. 13). Mean weekly length increased from about 32 mm to a little more than 34 mm FL between week 51 and week 5 (Fig. 13), then remained around 33.5 mm FL through week 15. (The size and number of fall-run yolk-sac fry beginning in week 14 when the smaller salmon are considered late-fall run).

Fall-run fry were caught from 17 December 1997 (week 51) through 24 April 1998 (week 17); 95% of the fry catch occurred from week 3 through week 14 (Fig. 12). Fry numbers peaked in week 10 (n = 31,659; Fig. 13). Fry lengths appeared to be normally distributed (Fig. 14); 99% of the measured fry were between 31 mm and 38 mm FL. Fry length ranged from 25 to 65 mm FL (mean = 34.9, SD = 1.49). Mean weekly fry length was relatively constant, ranging between 33 and 35 mm FL except during the last two weeks of their capture (weeks 16 and 17) when mean size was greater than 36.5 mm FL (Fig. 13), potentially a reflection of the change in classification of smaller salmon to late-fall run.

Fall-run parr were caught from 26 January 1998 (week 5) through 29 May 1998 (week 22) (Fig. 12). Parr lengths ranged from 25 mm to 89 mm FL (mean = 44.8 mm FL, SD = 11.6) (Figs. 13 and 14); 95% of the measured parr were between 33 mm and 68 mm FL (Fig. 14). A strong positive skew in parr length distribution (Fig. 14) suggests that the length at which salmon change from parr to silvery parr is more variable than the length at which they change from fry to parr. Mean weekly parr length varied only slightly between week 5 and week 15 (mean FL = 39.8, SD = 7.0), although the size range through week 15 was quite variable owing to a few, large (>60 mm FL) parr being captured during weeks 11 through 15 (Fig. 13). Mean weekly parr length steadily increased from week 16 through week 23, from 45 mm to a high of 69 mm FL in week 19 (Fig. 13).

Fall-run silvery parr were caught from 27 January (week 5) to 31 July 1998 (week 31) (Fig. 12). Catch peaked in week 21 (n = 489) (Fig. 13). There appeared to be two groups of emigrating silvery parr: The first group (n = 117) consisted of early (weeks 5 through 13), relatively small (mean <50 mm FL) migrating fall run. The second group generally increased in both number (n = 1,394) and size (mean >74 mm FL) starting in week 16 and peaking in week 21. Silvery parr lengths ranged from 42 mm to 98 mm FL (mean = 73.6 mm FL, SD = 8.1) (Figs. 13 and 14).

Mean weekly length increased from <45 mm FL in weeks 5 and 7, to over 70 mm FL in weeks 17 through 31 (Fig. 13).

Fall-run smolts were caught between 18 May and 25 June 1998 during weeks 21–23, 25 and 26 (Fig. 12). Fifty-four fall-run smolts were collected. Size ranged between 70 mm and 105 mm FL (mean = 90.9 mm FL, SD = 6.8) (Figs. 13 and 14).

Fall-run chinook salmon lengths varied significantly as a function of life stage (Kruskal-Wallis test of medians, $p<0.01$). Average length increased from about 33 mm FL in yolk-sac fry to 91 mm FL in smolts, although there was great overlap in size ranges in adjacent life stages as described above.

Condition Factor

Condition factor, K, was calculated for chinook salmon ≥45 mm FL to include only fish fully metamorphosed from the yolk-sac and fry stages (Table 5). There were no apparent difference in mean K of parr, silvery parr, and smolts although their medians differed significantly (Kruskal-Wallis test statistic = 19.2979, $p<0.0001$) (Note: ANOVA was not used because of significant differences in variances among groups and great disparity in sample sizes.) The most notable difference in K among life stages was the decline in maximum K with smolting (Fig. 15a). The condition factor of fry was not included for analysis because of that group's relatively very small sample size (Table 5).

Table 5. Condition factor (K) statistics by life stage for chinook salmon (≥45 mm FL) collected during the 1998 lower American River emigration survey, October 1997 through September 1998.

K	Fry	Parr	Silvery parr	Smolt
Minimum	0.66	0.72	0.75	0.70
Maximum	1.14	1.56	1.52	1.26
Mean	0.93	1.07	1.09	1.08
Standard deviation	0.18	0.12	0.10	0.10
Sample size	7	742	1,229	44

Salmon condition was also analyzed as a function of time (Table 6). Average K generally increased over time and differences in K between months were significant (Kruskal-Wallis test statistic = 146.516, $p = 0.0$). Again, a notable trend relative to smolting was the decrease in maximum K and reduction in the standard deviation of K in June (Fig. 15b) when all captured salmon analyzed for condition were silvery parr ($n = 73$) and smolts ($n = 16$).

In previous years (1994–1997), we have also considered K as a function of FL to assess whether condition decreased as salmon grew to the smolt stage, a common diagnostic in smolting salmonids. As seen previously, K increased very slightly on average with increasing length over the size range of salmon observed (slope $b = 0.0013$, size range 46–105 mm FL). Even though this relationship was significant as determined by linear regression ($p<0.0001$), the associated model explained little of the observed variation in K as a function of length ($r^2 = 0.015$) and thus has no reliable predictive utility. Even K of smolts alone did not provide evidence of decreasing condition relative to smolting in-river ($b = 0.0045$, $r^2 = 0.094$, $p<0.05$).

Table 6. Condition factor (K) statistics by month for chinook salmon (≥45 mm FL) collected during the 1998 lower American River emigration survey, October 1997 through September 1998.

K	February	March	April	May	June
Minimum	0.87	0.66	0.73	0.70	0.88
Maximum	1.27	1.36	1.49	1.56	1.27
Mean	1.02	1.02	1.07	1.10	1.07
Standard deviation	0.14	0.12	0.12	0.10	0.08
Sample size	8	229	427	1,269	88

Overall, these analyses show that condition of salmon increased slightly as the fish developed in-river, whether expressed as a function of size (FL), life stage, or time. The salmon could be regarded as being in "good" individual condition with K typically averaging near or above unity. K can provide a good, yet gross assessment of fish condition that does not require sacrificing fish. Analyzing fish dry weights to account for body weight in water, would likely provide a better assessment of salmon nutritional status as a function of size, life stage, time, or associated factors that reflect ambient environmental conditions such as stream flow and temperature.

Mark-recapture/ Trap Efficiency

Trap efficiency was measured from week 2 through 23 (5 January–7 June1998). Less than 100 fish were marked during weeks 19 and 23 and these weeks were procedurally removed from the data set for analysis. A total of 116,659 salmon was marked and 1,691 were recaptured for an overall trap efficiency of 1.45%. Percent recapture (efficiency) ranged from 0% (weeks18 and 20) to 3.85% (week 12) (Figs. 16; Table 7). Mean weekly trap efficiency was 1.09% (SD = 0.97, 80% CI = 0.80–1.38).

Correlation analyses were run to determine the strength of the relationship between each of eight independent variables and trap efficiency (Table 8). Moderately strong and significant correlations occurred only with weekly total trapping effort and weekly mean trap rotation rate

Table 7. Results of rotary screw trap efficiency evaluation conducted with marked chinook salmon during the 1998 lower American River emigration survey, October 1997 through September 1998.

Week	Number salmon marked	Number salmon recaptured	Efficiency (% recaptured)
2	1,368	9	0.66
3	2,469	10	0.41
4	9,797	83	0.85
5	18,387	357	1.94
6	9,662	183	1.89
7	11,044	39	0.35
8	12,010	33	0.27
9	14,200	117	0.82
10	17,937	373	2.08
11	11,654	262	2.25
12	5,324	205	3.85
13	492	3	0.61
14	288	2	0.69
15	268	2	0.75
16	326	2	0.61
17	280	4	1.43
18	140	0	0.00
19[1/]	12	0	0.00
20	318	0	0.00
21	342	1	0.29
22	297	6	2.02
23[1/]	44	0	0.00
Total	116,659	1,691	1.45 (weekly mean = 1.09)

1/ Fish marked during weeks 19 and 23 were not included in the weekly efficiency analysis since fewer than 100 fish were marked and released during these weeks. Protocol requires that at least 100 marked fish are released during any week to provide a measurement of weekly efficiency.

Table 8. Correlation matrix of weekly rotary screw trap capture efficiency for juvenile chinook salmon, and (i) number of salmon marked per week for efficiency tests, (ii) total salmon catch per week, (iii) weekly mean salmon FL, (iv) weekly mean water temperature, (v) weekly mean water turbidity (NTU), (vi) weekly mean river flow, (vii) weekly total trapping effort, and (viii) weekly mean trap rotation rate, during lower American River emigration surveys in 1995–1996, 1996–1997, and 1997–1998.

Season	No. salmon marked	Total salmon catch	Mean FL	Mean water temp.	Mean trans-parency	Mean river flow	Total trapping effort	Mean trap RPM
1995–96	–0.02	0.20	–0.08	0.11	–	–0.02	0.11	–
1996–97	–0.38	–0.31	0.12	0.76[1/]	–0.05	0.05	0.26	0.13
1997–98	0.35	0.34	–0.19	–0.24	–0.11	–0.24	–0.54[1/]	–0.70[1/]

1/ Denotes a significant correlation at $p \leq 0.05$.

(RPM). However, results from the three seasons of measuring trap efficiencies on the lower American River as described herein (1996, 1997, and 1998), have not shown any consistent relationship between trap efficiency and the independent variables measured (Table 8). Only one other significant correlation has been observed and correlations with each variable have included conflicting positive and negative correlations in different years. Thus, the significant correlations observed are regarded as spurious, especially in light of multiple regression analyses for these years which have not produced any consistent, compelling results regarding the influence of these independent variables (both alone and in combination) on trap efficiency (R. Titus, unpubl. analyses).

Since screw trap efficiency on the lower American River does not vary consistently with any measured variable within observed ranges and levels of measurement resolution, and to allow for determination of confidence intervals using standard statistical methods (e.g., Zar 1984), abundance estimates were calculated using the mean of weekly trap efficiency estimates (see below).

Estimated Abundance of Emigrating Fall-run Chinook Salmon

The total number of fall-run chinook salmon emigrating from the lower American River in 1998 was estimated using the mean trap efficiency of 1.09%. The total number of captured fall run (n = 194,416) was expanded to account for the time that the traps were not fishing. The estimated number of fall-run salmon juveniles that would have been caught if the traps had fished 100% of the time when fall run were present was 206,348. This estimate was divided by the mean efficiency to yield an estimated 18.9 million salmon. This estimate is intended to be used as an index of emigration rather than an absolute measurement.

Spring-run-sized Chinook Salmon

Spring-run-sized juvenile chinook salmon were periodically captured between week 4 and week 20 (Table 9). In total, 28 spring-run-sized chinook juveniles were collected. Nineteen of the 28 were marginally larger than the minimum size criterion (i.e., within 3 mm FL) defining spring run for the date captured. One spring-run-sized salmon was classified as a fry, 9 as parr and 18 as silvery parr.

Winter-run-sized Chinook Salmon

Thirteen juvenile winter-run-sized chinook salmon were collected by RST (Table 10). These fish were captured between 10 December 1997 and 15 March 1998. All winter run were well within the size range defining winter-run juveniles for the dates of capture (at least 20 mm FL larger than the minimum size criteria). Six of the winter-run-sized salmon were classified as parr; seven were classified as silvery parr.

Late-fall-run-sized Chinook Salmon

One yearling-sized late-fall-run chinook salmon was collected (113 mm FL on 17 November 1997). As discussed above, the size-at-time criteria used to classify chinook salmon race defines recently emerged-sized salmon as late-fall run beginning 1 April. We collected 371 recently emerged salmon between 1 April and 8 May 1998 that were classified as late-fall run (Table 11). The size range for these 371 salmon was 30–38 mm FL (mean = 33.5, SD = 1.45). Most of the YOY late-fall run (209 fish) were collected during week 16 (12–18 April 1998).

Steelhead Trout

Juvenile steelhead captured in the RSTs represented two groups: young-of-the-year (typically <100 mm FL), and in-river produced yearlings (typically 100–300 mm FL) (Table 12).

A total of 115 YOY steelhead was captured between week 13 (26 March 1998) and week 33 (12 August 1998) (Fig. 17). Most YOY (69%) were captured during weeks 20–23; 95.7% were caught before week 24. The highest weekly catch occurred during week 22 (43 fish). Mean weekly length ranged from 25 mm FL (weeks 14 and 15) to 97 mm FL in week 31 (Fig. 18).

Life stage was identified for 102 YOY steelhead (Table 13). One was classified as a yolk-sac fry, 60 as fry, 38 as parr, and 3 as silvery parr.

Two, in-river-produced, yearling steelhead were caught; one in week 16 (18 April 1998) and one in week 21 (22 May 1998) (Table 12; Fig. 17). Fish lengths were 271 and 290 mm FL (Fig. 18). Both yearling steelhead were classified as smolts (Table 13).

Table 9. Summary of catch statistics for spring-run-sized chinook salmon collected during the 1998 lower American River emigration survey, October 1997 through September1998.

Week	Beginning date	Total catch	Size statistics			
			Mean	Min	Max	SD
4	18 Jan 1998	1	47	47	47	
7	8 Feb 1998	1	55	55	55	
11	8 Mar 1998	3	67	65	69	1.63
12	15 Mar 1998	3	69	68	69	0.47
13	22 Mar 1998	2	77	70	84	7.00
15	5 Apr 1998	1	76	76	76	
16	13 Apr 1998	3	89	82	99	7.26
17	19 Apr 1998	1	92	92	92	
18	27 Apr 1998	7	90	83	95	3.01
19	4 May 1889	4	95.3	85	104	6.91
20	11 May 1998	2	95	95	95	
	Total	28				

Table 10. Summary of catch statistics for winter-run-sized chinook salmon collected during the 1998 lower American River emigration survey, October 1997 through September1998.

Week	Beginning date	Total catch	Size statistics			
			Mean	Min	Max	SD
50	10 Dec 1997	1	77.0	77	77	
2	5 Jan 1998	1	78.0	78	78	
3	12 Jan 1998	4	105.3	101	110	3.27
5	25 Jan 1998	3	91.3	85	97	4.92
9	22 Feb 1998	1	113.0	113	113	
11	8 Mar 1998	1	111.0	111	111	
12	15 Mar 1998	2	110.0	110	110	
	Total	13	97.9	77	113	1.17

Table 11. Summary of catch statistics for late-fall-run-sized chinook salmon collected during the 1998 lower American River emigration survey, October 1997 through September1998.

Week	Beginning date	Total catch	Size statistics			
			Mean	Min	Max	SD
47	16 Nov 1997	1	113	-	-	-
14	29 Mar 1998	56	32.3	31	33	0.76
15	5 Apr 1998	65	32.8	30	34	1.07
16	12 Apr 1998	209	34.0	30	36	1.34
17	19 Apr 1998	38	33.7	30	38	1.69
18	26 Apr 1998	2	36.5	35	38	1.5
19	3 May 1998	1	35	-	-	-
	Total	372				

Table 12. Catch statistics for steelhead caught during the 1998 lower American River emigration survey, October 1997 through September1998.

Week	Young of the year		Yearling (in-river)	
	Count	Mean FL (mm) and range	Count	Mean FL (mm) and range
1–12	No steelhead captured		No steelhead captured	
13	2	26.5 (25-28)	0	
14	5	25.2 (22-28)	0	
15	7	25.5 (23-29)	0	
16	9	27.2 (24-32)	1	271.0 (271-271)
17	4	30.5 (27-33)	0	
18	3	30.3 (25-34)	0	
19	1	25.0 (25-25)	0	
20	11	43.1 (36-51)	0	
21	17	49.5 (36-58)	1	290.0 (290-290)
22	43	49.0 (30-65)	0	
23	8	47.0 (35-66)	0	
24	1	53.0 (53-53)	0	
25	0		0	
26	0		0	
27	0		0	
28	1	92.0 (92-92)	0	
29	0		0	
30	0		0	
31	1	97.0 (97-97)	0	
32	0		0	
33	2	88.5 (86-91)	0	
Total	115	47.3 (22-97)	2	280.5 (271-290)

Table 13. Life stage composition by age for steelhead caught during the 1998 lower American River emigration survey, October 1997 through September1998.

	Young of the year		Yearling (in-river)	
Life stage	Count	Mean FL (mm) and range	Count	Mean FL (mm) and range
Yolk-sac fry	1	25	0	
Fry	60	38 (22-66)	0	
Parr	38	49.3 (30-65)	0	
Silvery parr	3	89.67 (86-92)	0	
Smolts	0		2	280.5 (270-290)

DISCUSSION

The estimated number of juvenile emigrants appears to be strongly influenced by flow during the incubation period (primarily January).

Mean flow in January 1998 (5,713 cfs) reflected the lower flow conditions in early January and the modest flood flow in late January (compared with 1995 and 1997). Those years when January flows were stable and flood events were absent (flow <25,000 cfs in January 1994, 1996 and 1998) yielded the highest, estimated total emigration population (total catch/mean efficiency), whereas the lowest population estimates occurred during years with high peak and mean January flows (1995 and 1997) (Appendix II).

The estimated total emigration population was not related to spawner population ($r^2 = 0.0001$) (Appendix II). The highest estimated spawner escapement (68,000 salmon in 1995) yielded the second highest emigration population estimate (1996 survey year); the second highest estimated spawner escapement estimate (67,000 salmon in 1996) yielded the lowest emigration population estimate (1997 survey year). The highest estimated emigration population occurred in the 1994 survey year following the second lowest spawner escapement population (28,754 in 1993). The estimated emigration population in 1998 was the second highest measured during the 5 survey years, while the estimated escapement was essentially median between the highest estimates observed in 1996 and 1997, and the lowest estimates observed in 1994 and 1995.

An index of survival to emigration (estimated emigration population/escapement estimate) was negatively correlated with both mean January flow and peak January flow ($r = -0.766$) (Appendix II).

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APPENDICES

Appendix I. Comparison of results from lower American River emigration surveys conducted 1994 through 1998.

	Year				
	1994	1995	1996	1997	1998
Salmon emigration start date (fall run juveniles)	Week 2 (of 1994)	Week 51 (of 1994)	Week 48 (of 1995)	Week 51 (of 1996)	Week 51 (of 1997)
Salmon emigration end date	Week 28	Week 32	Week 29	week 25[1/]	Week 31
Date of peak salmon catch	23 Feb	24 Feb	26 Jan	25 Feb	7 Mar
Maximum daily salmon catch	14,887	3,371	12,285	3,083	9,219
Maximum daily salmon catch rate	677 fish/h	141 fish/h	614 fish/h	54 fish/h	397 fish/h
Total estimated salmon catch	162,089	45,478	132,040	32,064	194,819
Total estimated steelhead catch	43	30	145	112	117
Average juvenile salmon catch	30.4 fish/h	9.6 fish/h	25.6 fish/h	7.4 fish/h	21.9 fish/h
Salmon life stage composition					
Yolk-sac fry	96.7%[2/]	3.5%	22.3%	12.5%	14.6%
Fry		70.5%	50.7%	35.8%	79.0%
Parr	1.6%	25.5%	20.6%	47.7%	5.5%
Silvery parr	1.4%	0.1%	2.3%	3.9%	0.8%
Smolt	0.3%	0.4%	--	0.01%	0.03%
Salmon condition factors (mean)					
Yolk-sac fry	0.79[2/]	0.93	0.74	0.87[3/]	--
Fry		0.74	0.69	0.75	0.96
Parr	1.02	0.78	0.77	0.92	1.08
Silvery parr	1.07	1.05	1.11	1.08	1.10
Smolt	1.14	1.15	--	1.09	1.08

1/ Trapping was ended before catches reached zero.
2/ Yolk-sac fry and fry combined as one life stage in 1994.
3/ Only includes fish ≥40 mm FL

Appendix II. Comparison of results from lower American River emigration surveys conducted 1994 through 1998 and corresponding spawner escapement and incubation flows.

	Year				
	1994	1995	1996	1997	1998
Total catch (fall run)	162,089	45,478	132,040	32,064	194,409
Mean efficiency	0.72	0.72[1/]	0.68	0.75	1.09
Estimated emigration population	18.2 million	5.9 million	20.3 million	4.3 million	18.9 million
Spawner escapement	28,754	27,733	65,972	67,000	46,888
Emigration survival index	633	213	308	64	405
Mean January flow	1,755	8,552	2,186	32,617	5,713

1/ Estimated as the mean efficiency observed during 1994, 1996 and 1997.

FIGURES

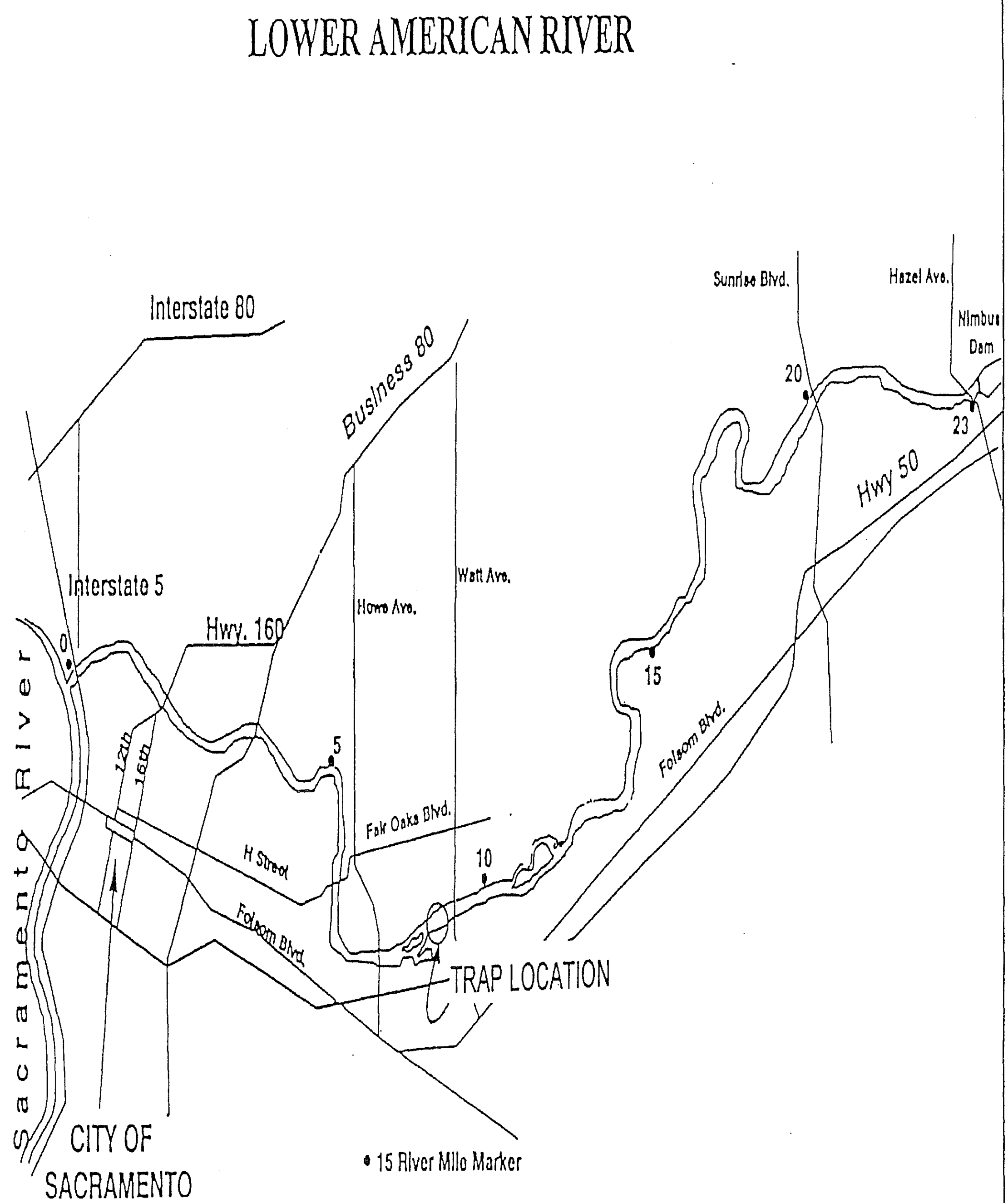

Figure 1. General location of the rotary screw traps used during the lower American River emigration survey,

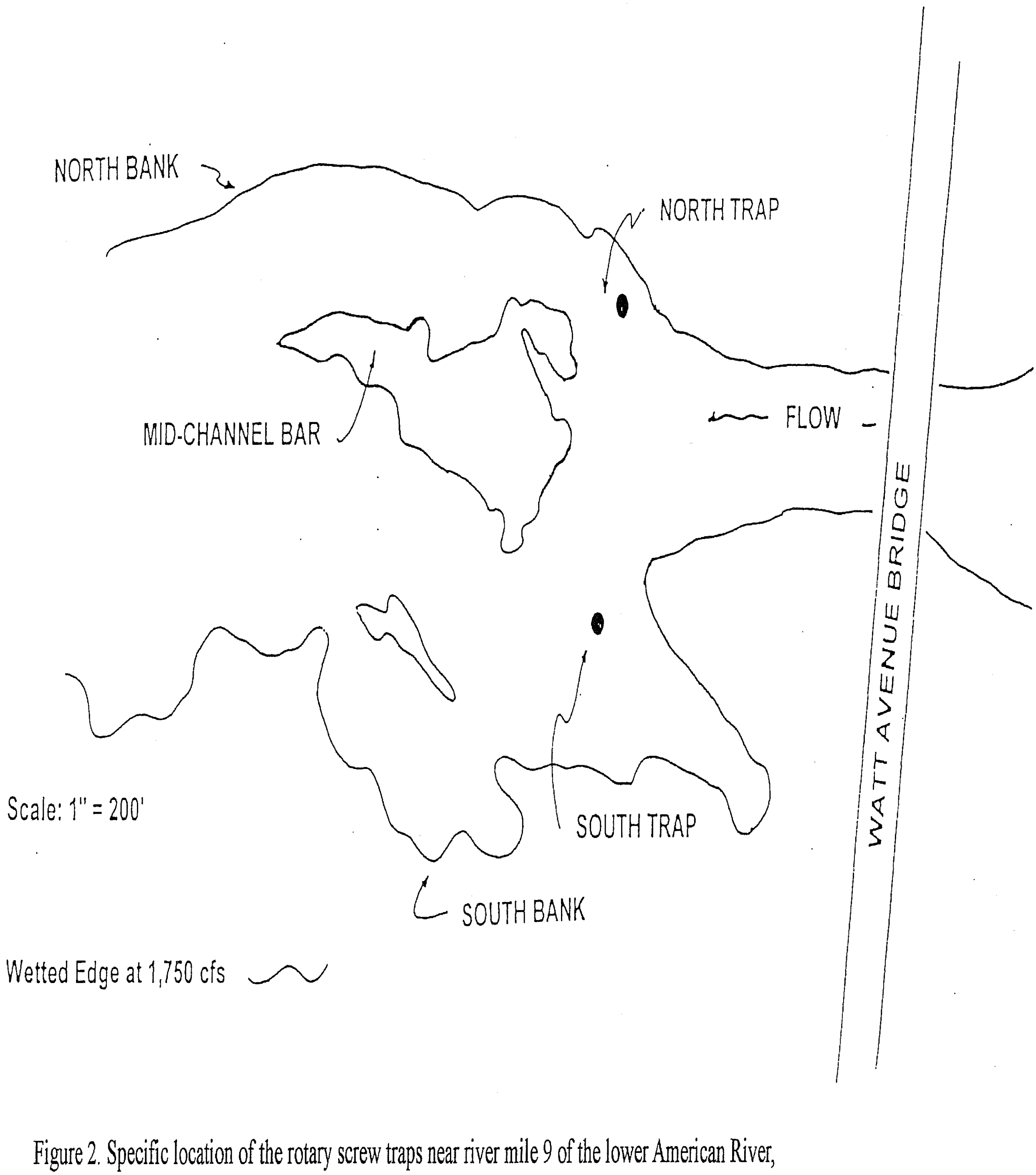

Figure 2. Specific location of the rotary screw traps near river mile 9 of the lower American River,

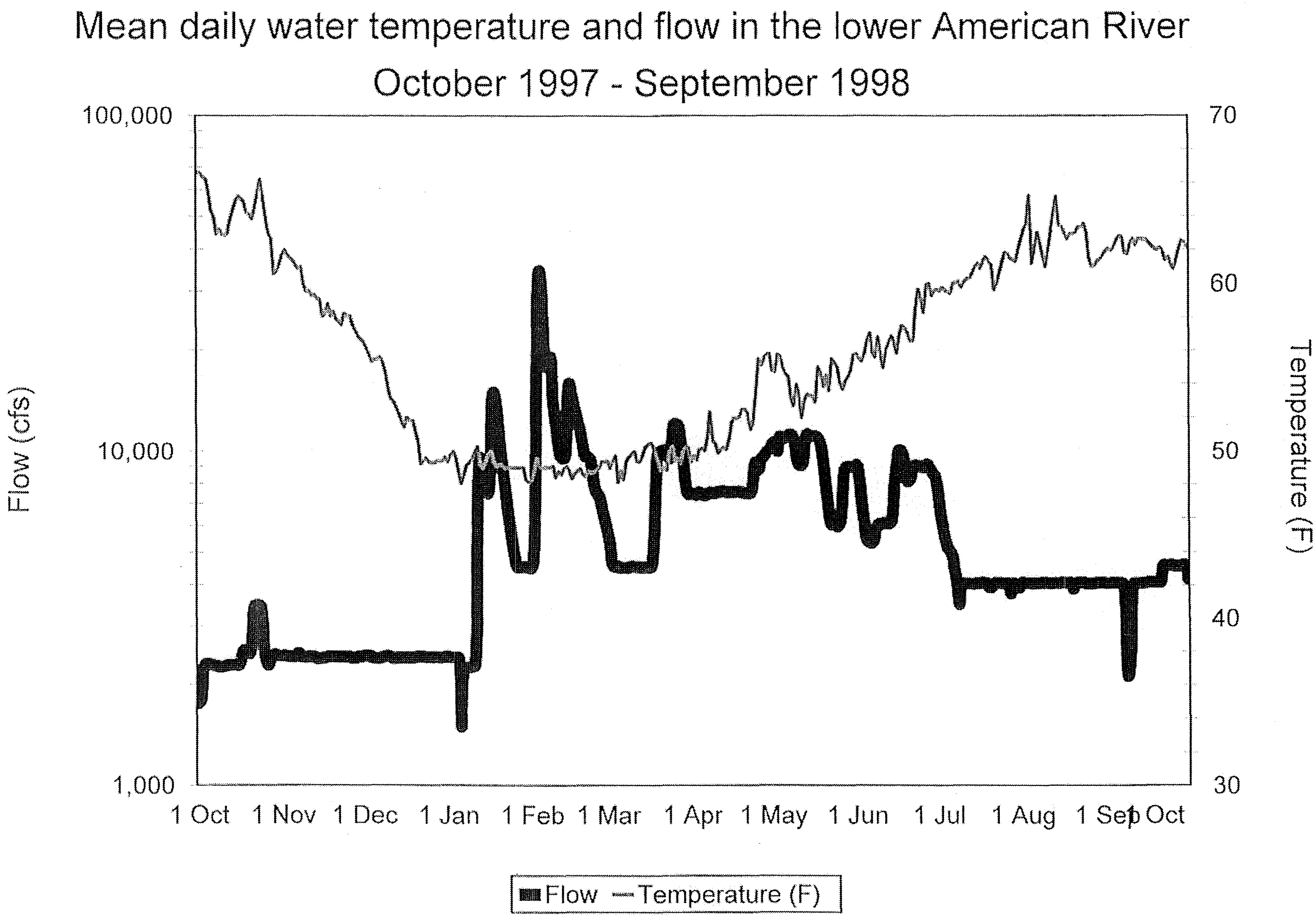

Figure 3. Mean daily flow (cfs), measured at Nimbus Dam, and water temperature (F), measured at Watt Avenue, during the lower American River emigration survey, October 1997 through September 1998.

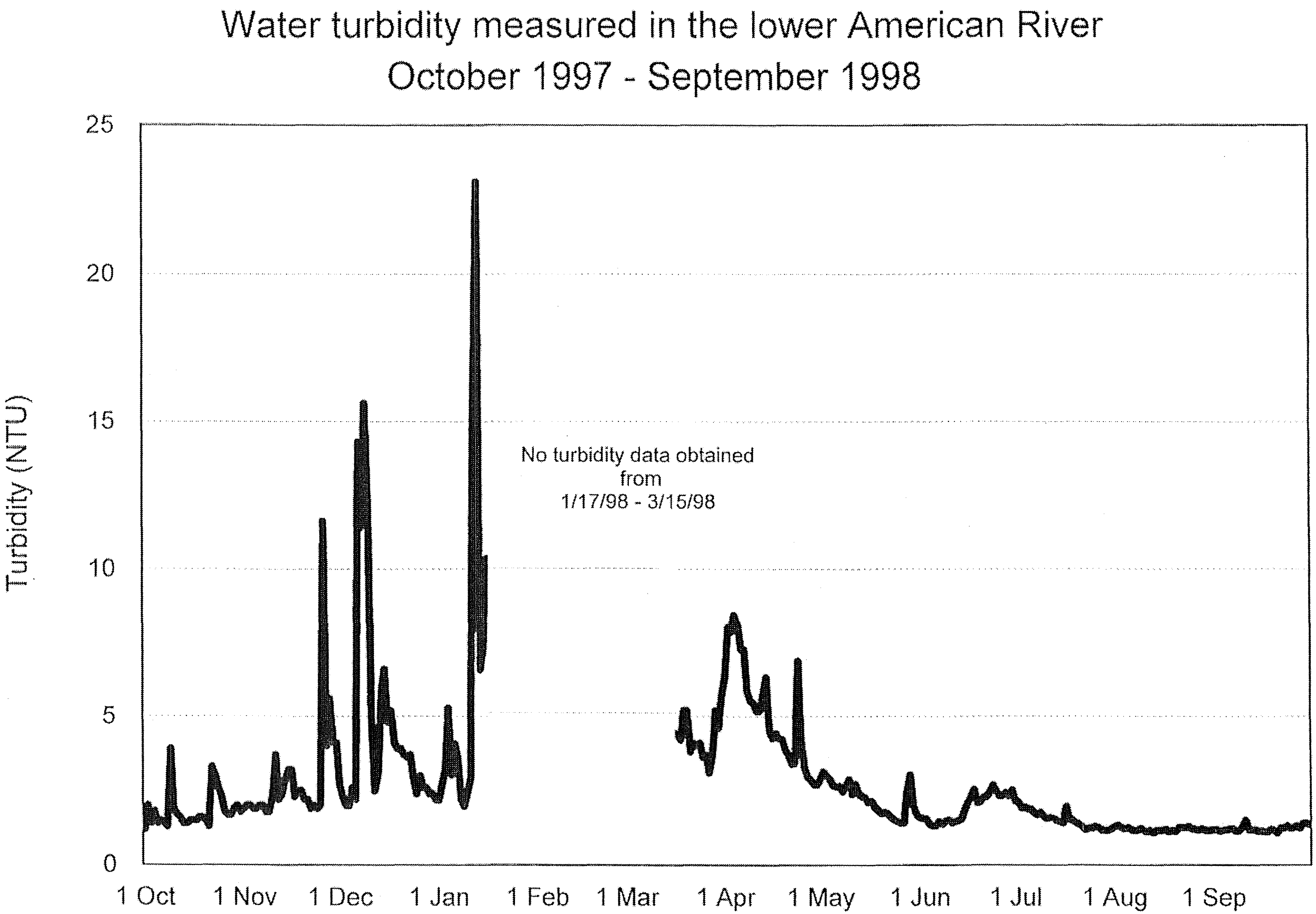

Figure 4. Water turbidity (NTU) measured in the lower American River at the Fairbairn Water Treatment Plant during the lower American River emigration survey, October 1997 through September 1998.

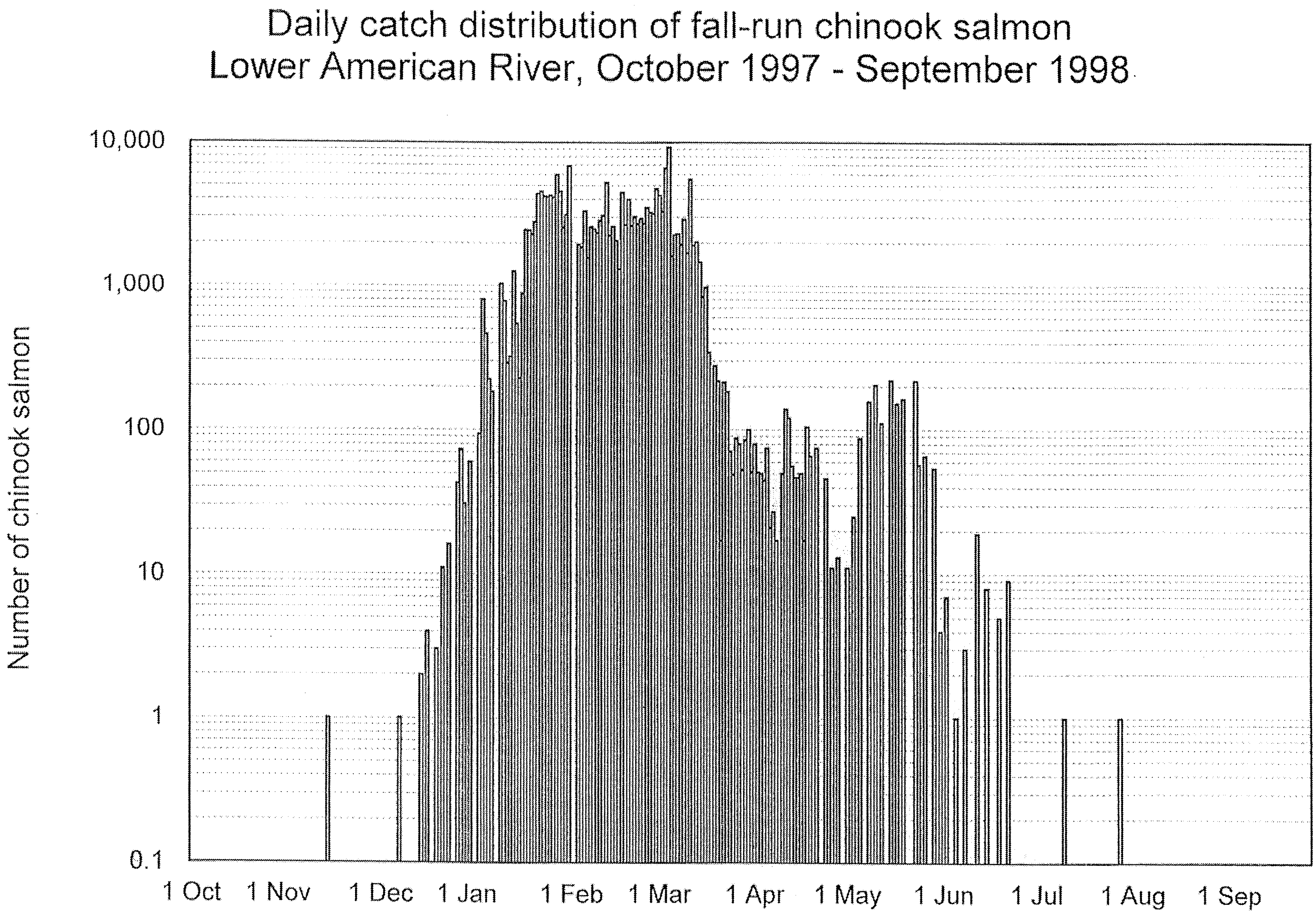

Figure 5. Daily catch distribution of fall-run chinook salmon caught by screw trap during the 1998 lower American River emigration survey, October 1997 through September 1998.

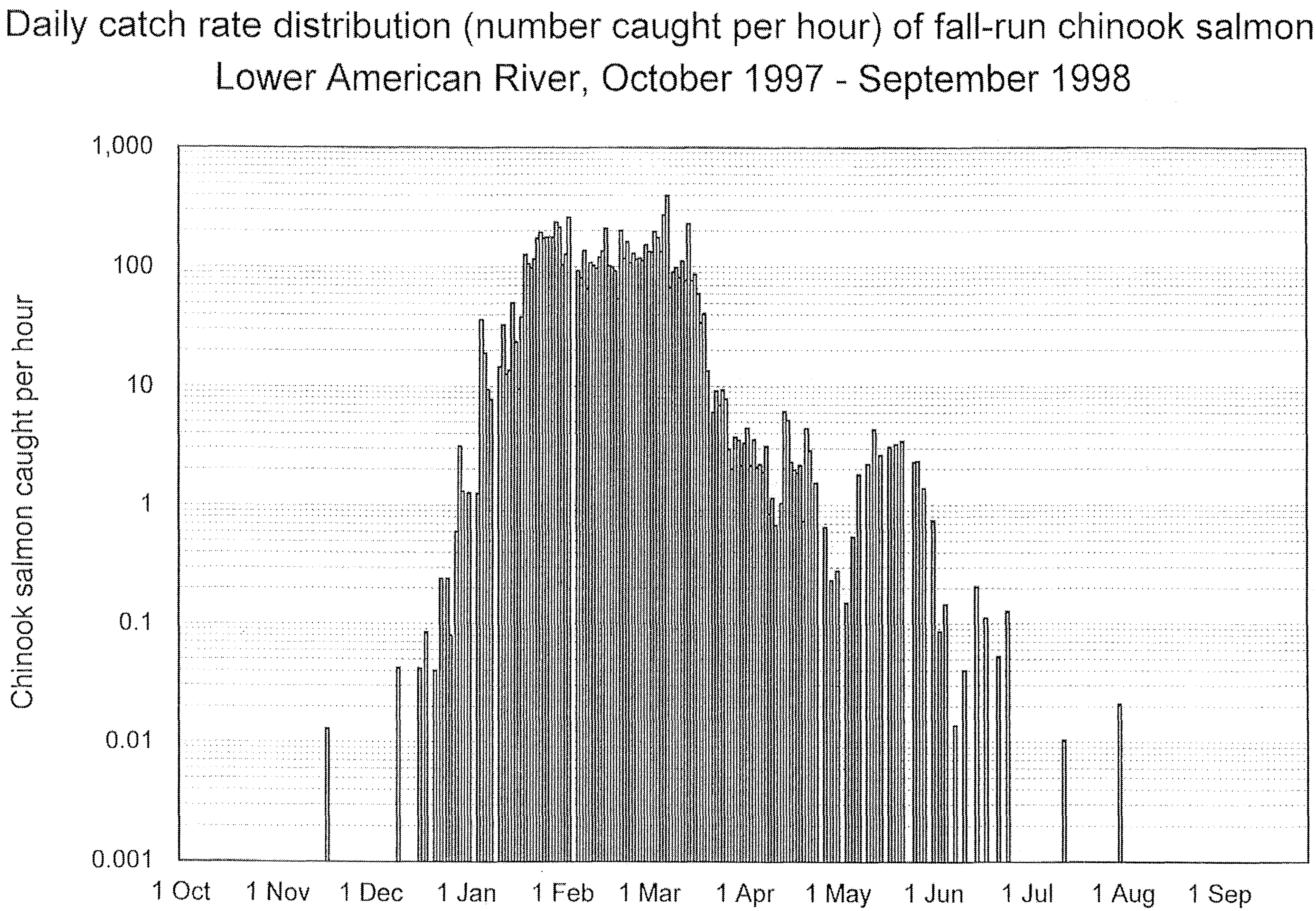

Figure 6. Daily catch rate (n/ hour) of fall-run chinook salmon caught by screw trap during the 1998 lower American River emigration survey, October 1997 through September 1998.

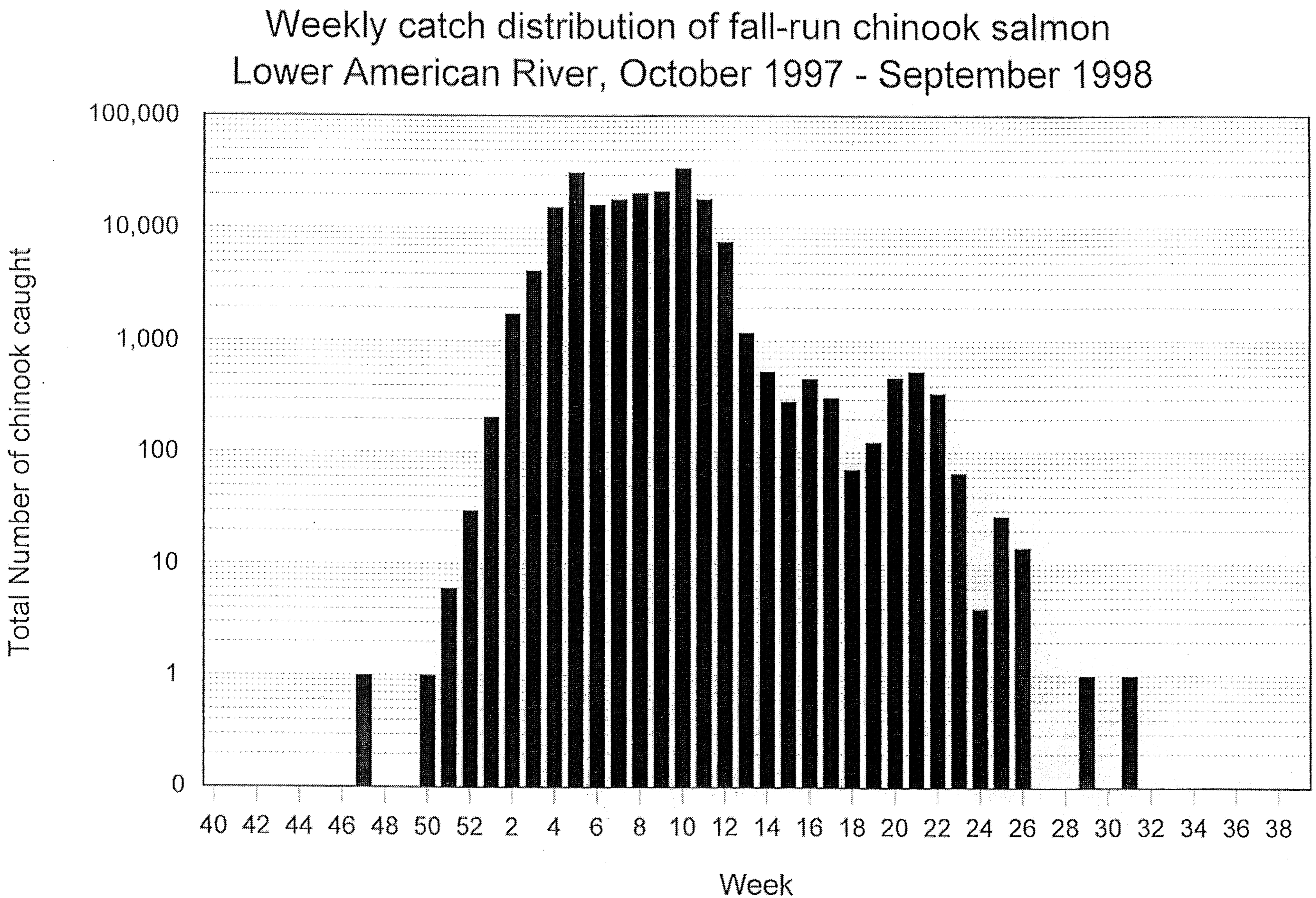

Figure 7. Weekly catch of fall-run chinook salmon caught by rotary screw trap during the lower American River emigration survey, October 1997 through September 1998.

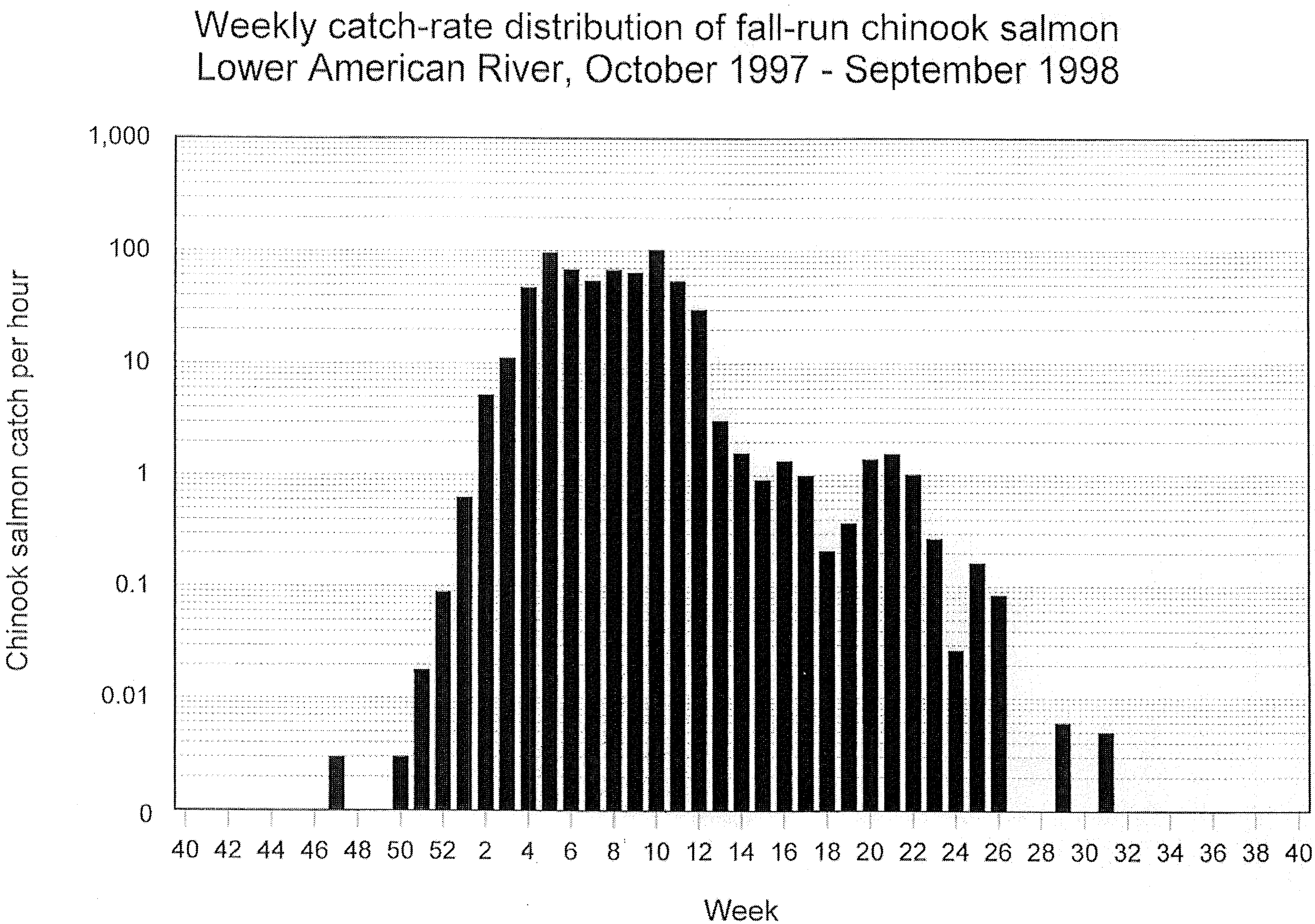

Figure 8. Weekly catch rate (n/hour) for fall-run chinook salmon caught by rotary screw trap during the lower American River emigration survey, October 1997 through September 1998.

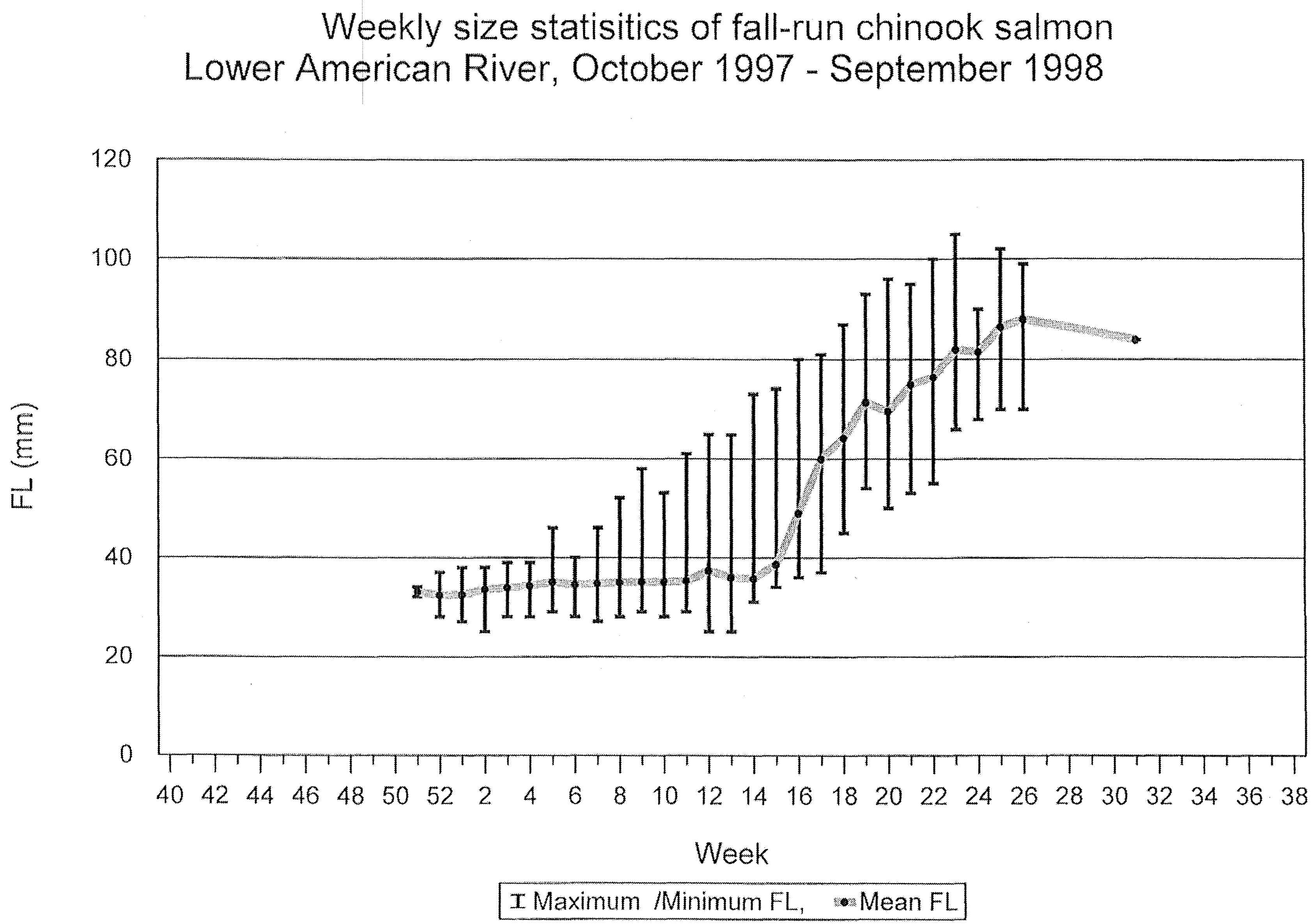

Figure 9. Mean weekly fork length and size range of fall-run chinook salmon caught by screw trap during the 1998 lower American River emigration survey, October 1997 through September 1998.

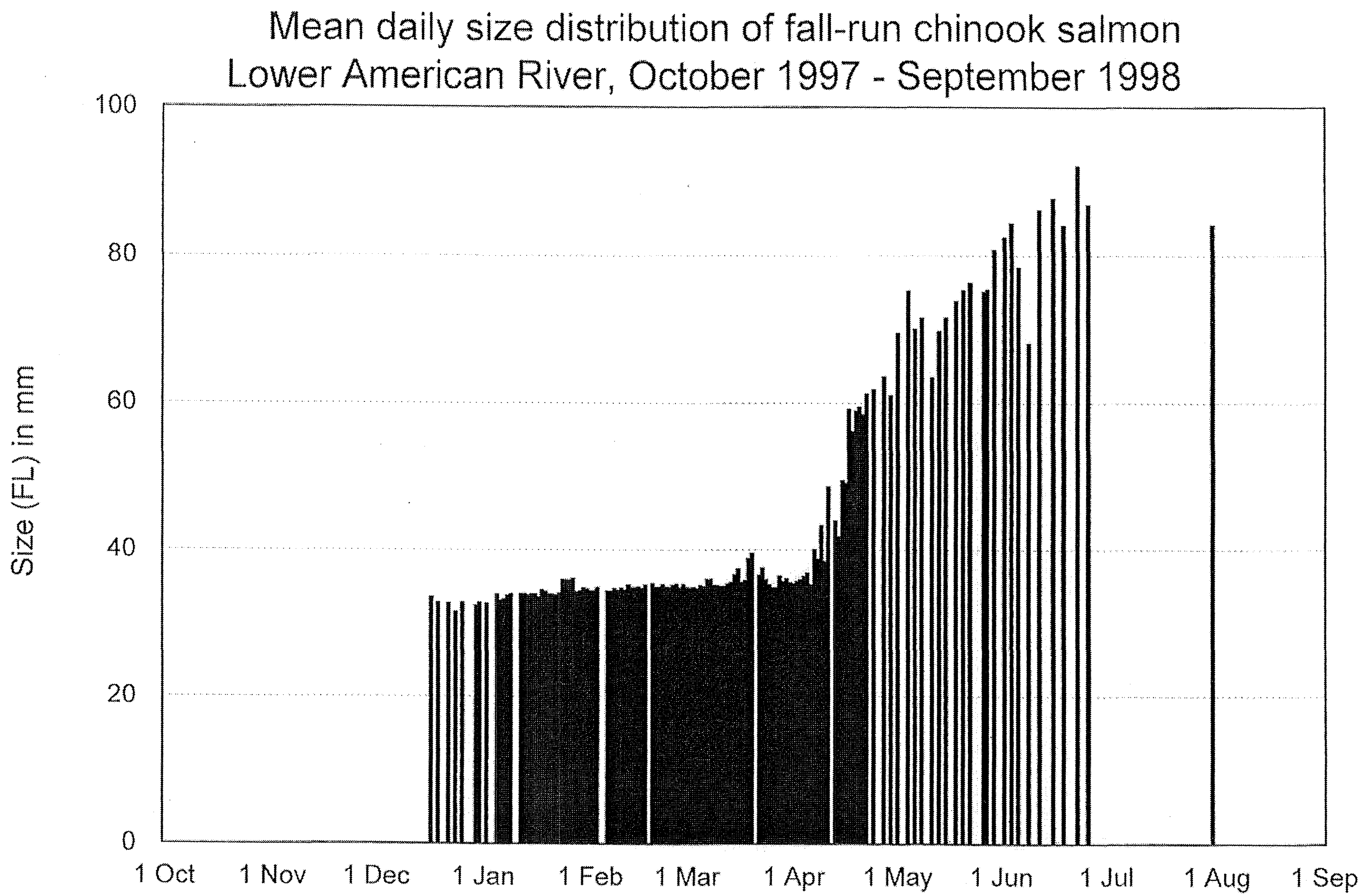

Figure 10. Mean daily fork length of fall-run chinook salmon caught by screw trap during the 1998 lower American River emigration survey, October 1997 through September 1998.

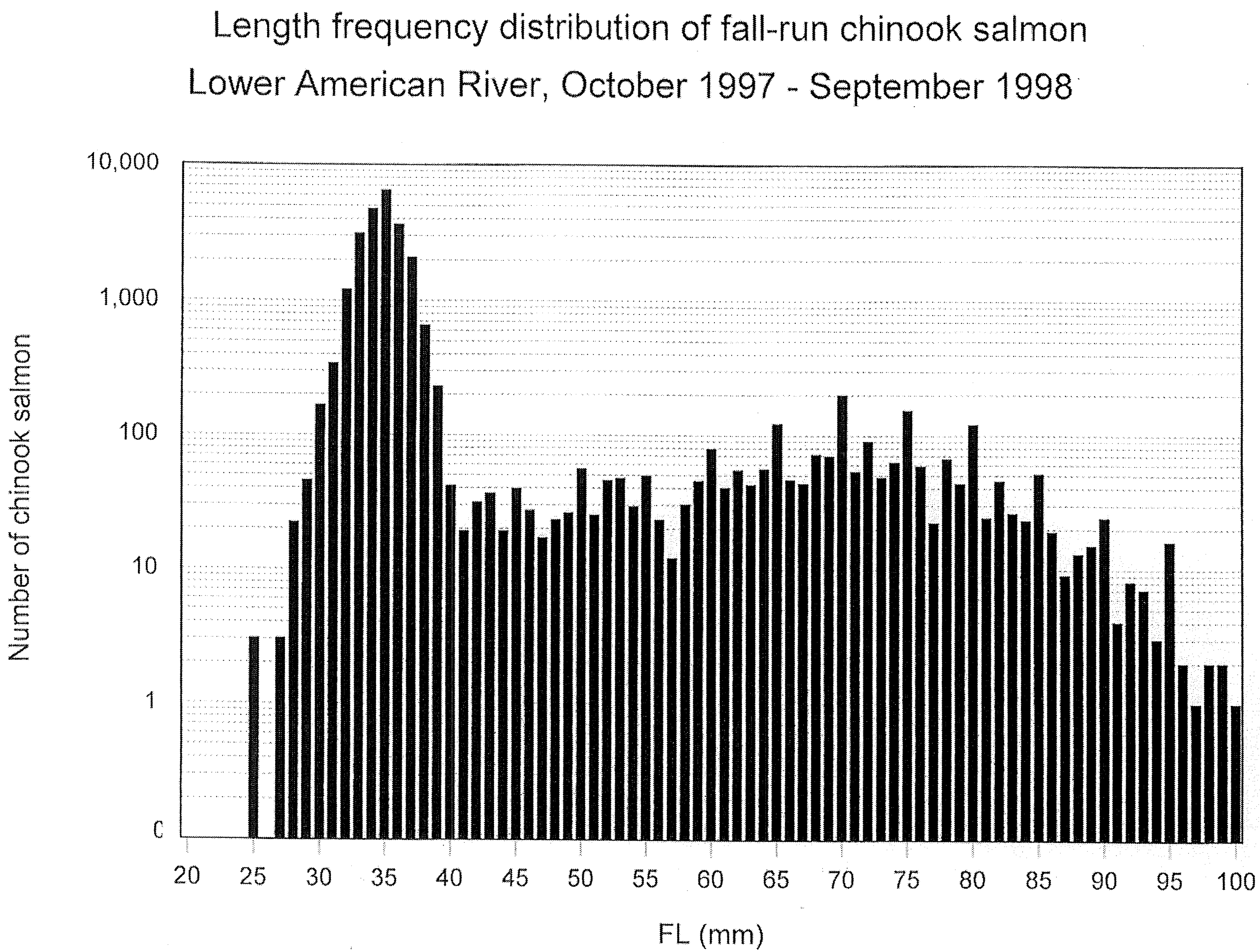

Figure 11. Length frequency distribution of fall-run chinook salmon caught by rotary screw trap during the 1998 lower American River emigration survey, October 1997 through September 1998.

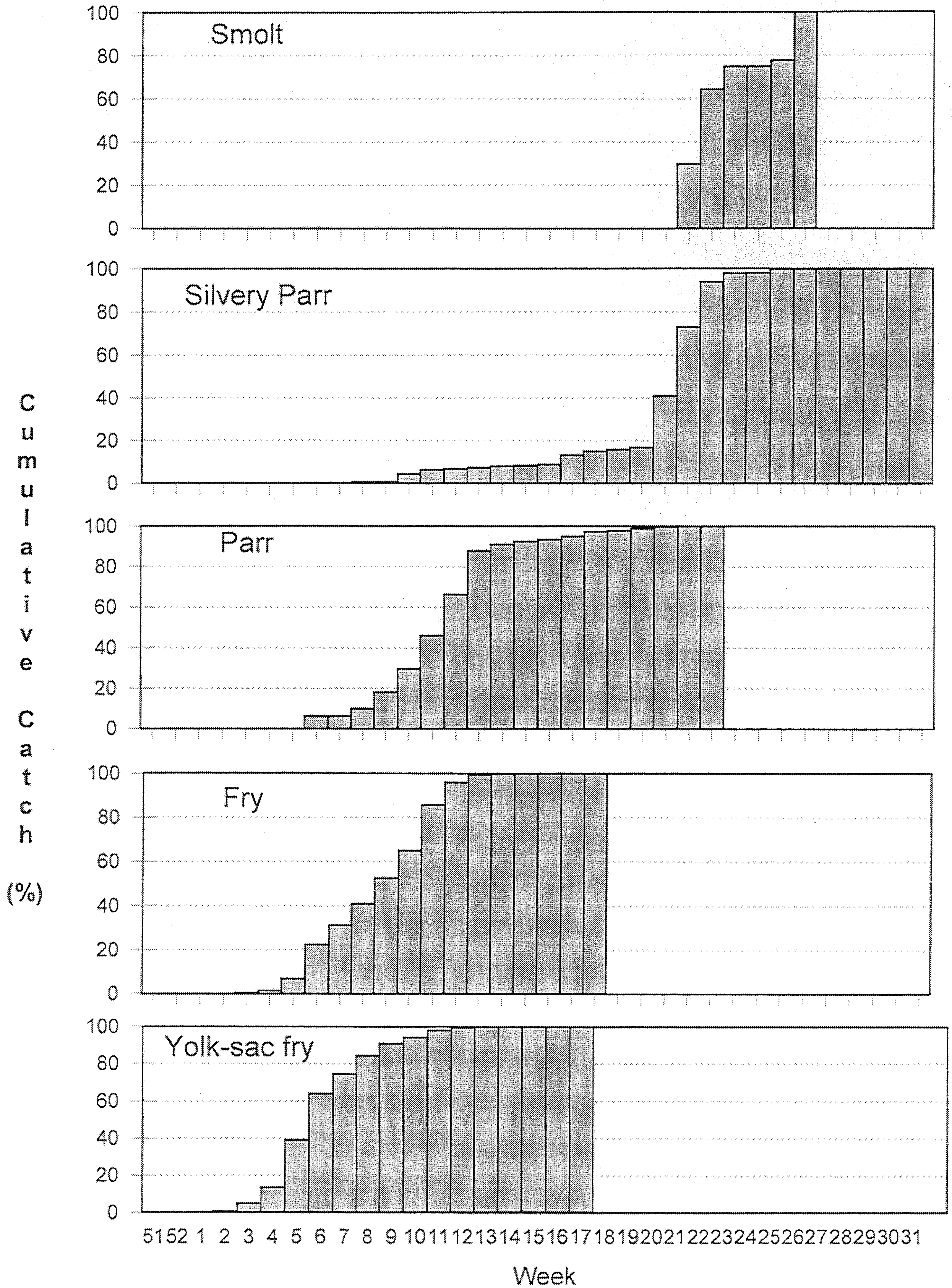

Figure 12. Cumulative catch (%) for fall-run chinook salmon yolk-sac fry, fry, parr, silvery parr and smolts collected during the lower American River emigration survey, October 1997 through September 1998.

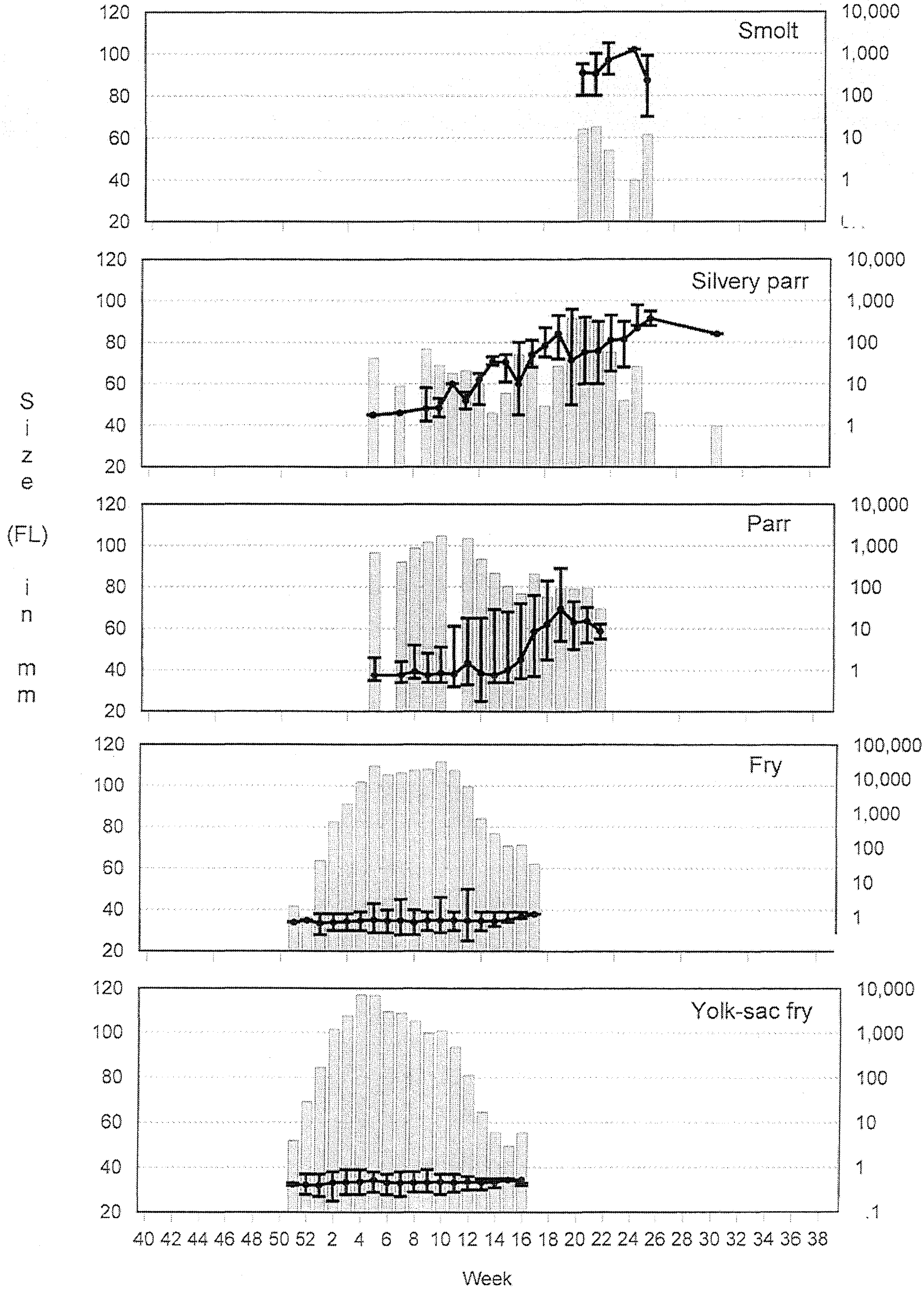

Figure 13. Weekly size and catch distribution of fall-run chinook salmon yolk-sac fry, fry, parr, silvery parr and smolts collected by rotary screw trap during the lower American River emigration survey, October 1997 through September 1998.

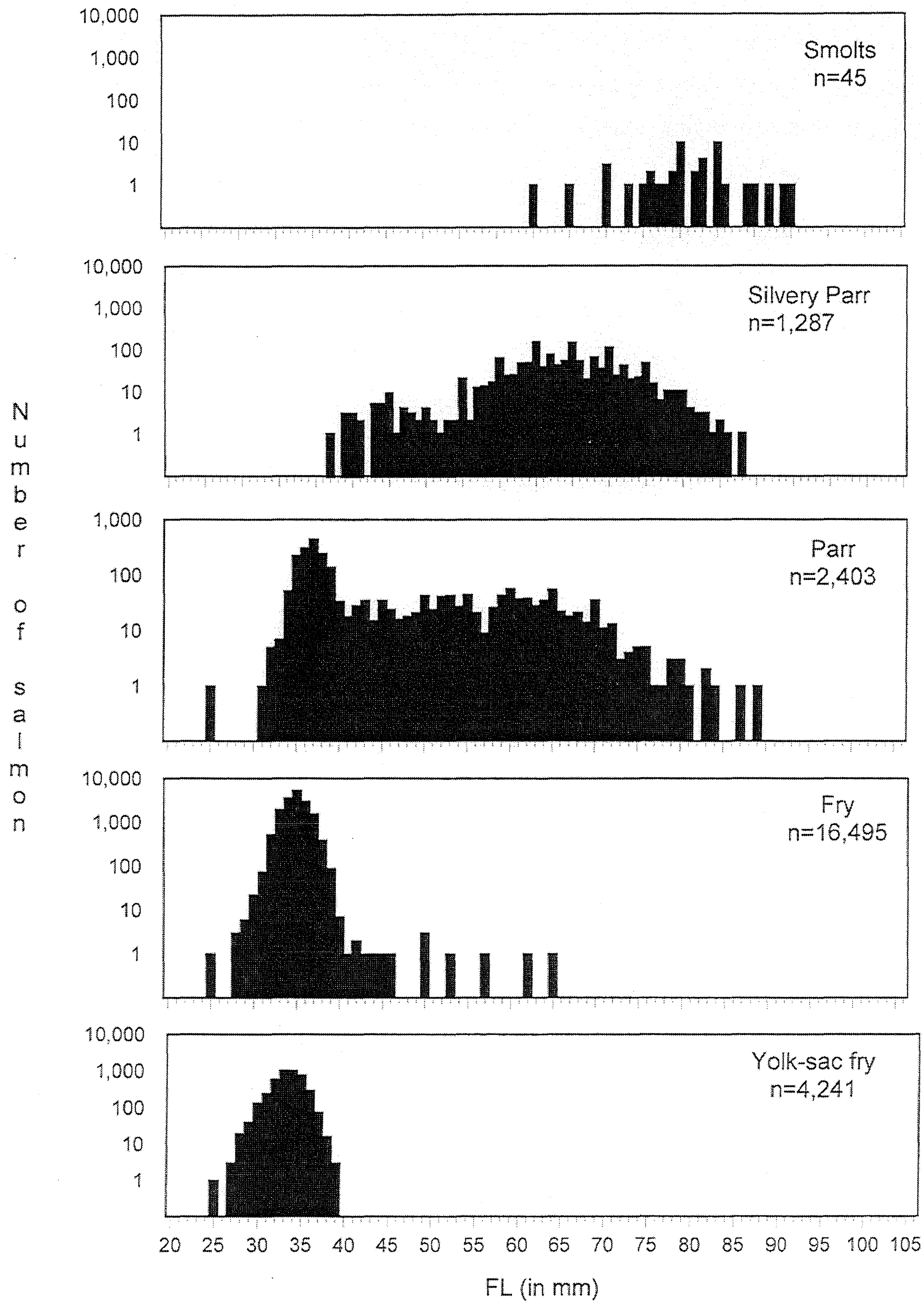

Figure 14. Length frequency distribution of fall-run chinook salmon yolk-sac fry, fry, parr, silvery parr and smolts collected during the lower American River emigration survey, October 1997 - September 1998.

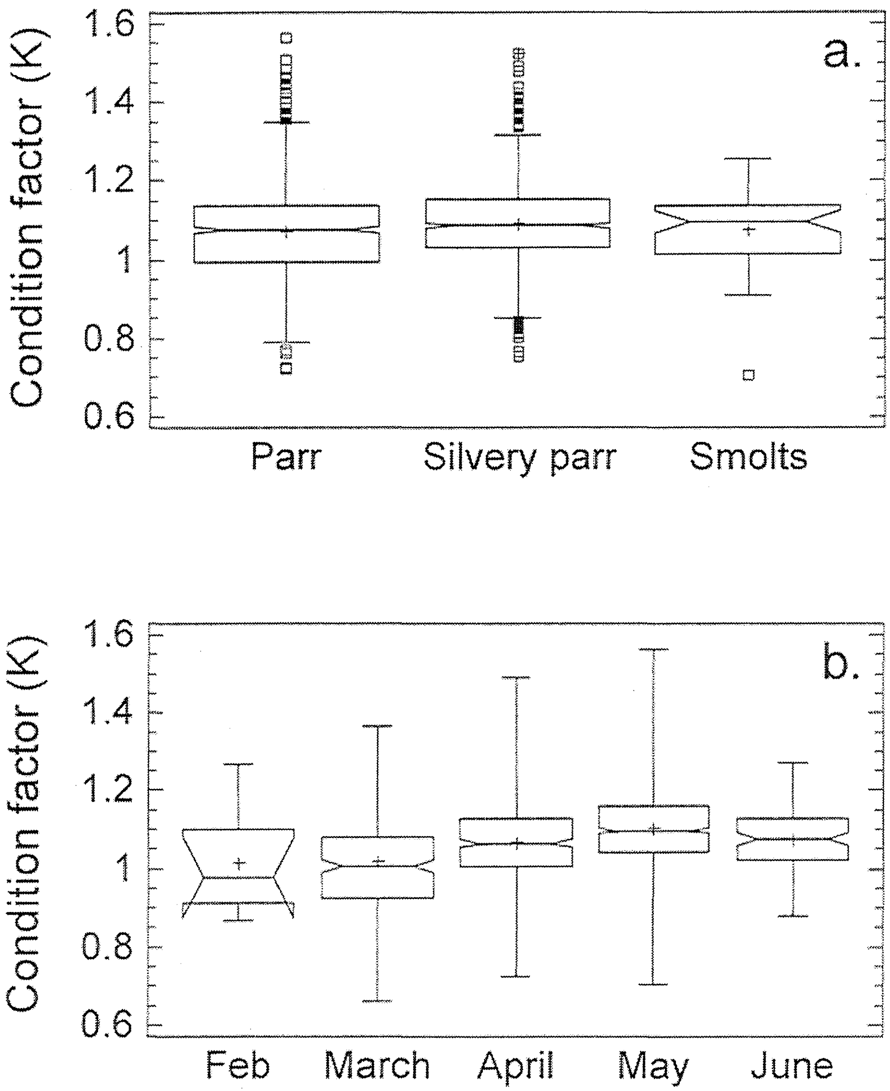

Figure 15. Condition factor (*K*) of juvenile chinook salmon as a function of (a) life stage, and (b) month of capture by screw trap, during the 1998 lower American River emigration survey, October 1997 through September 1998.

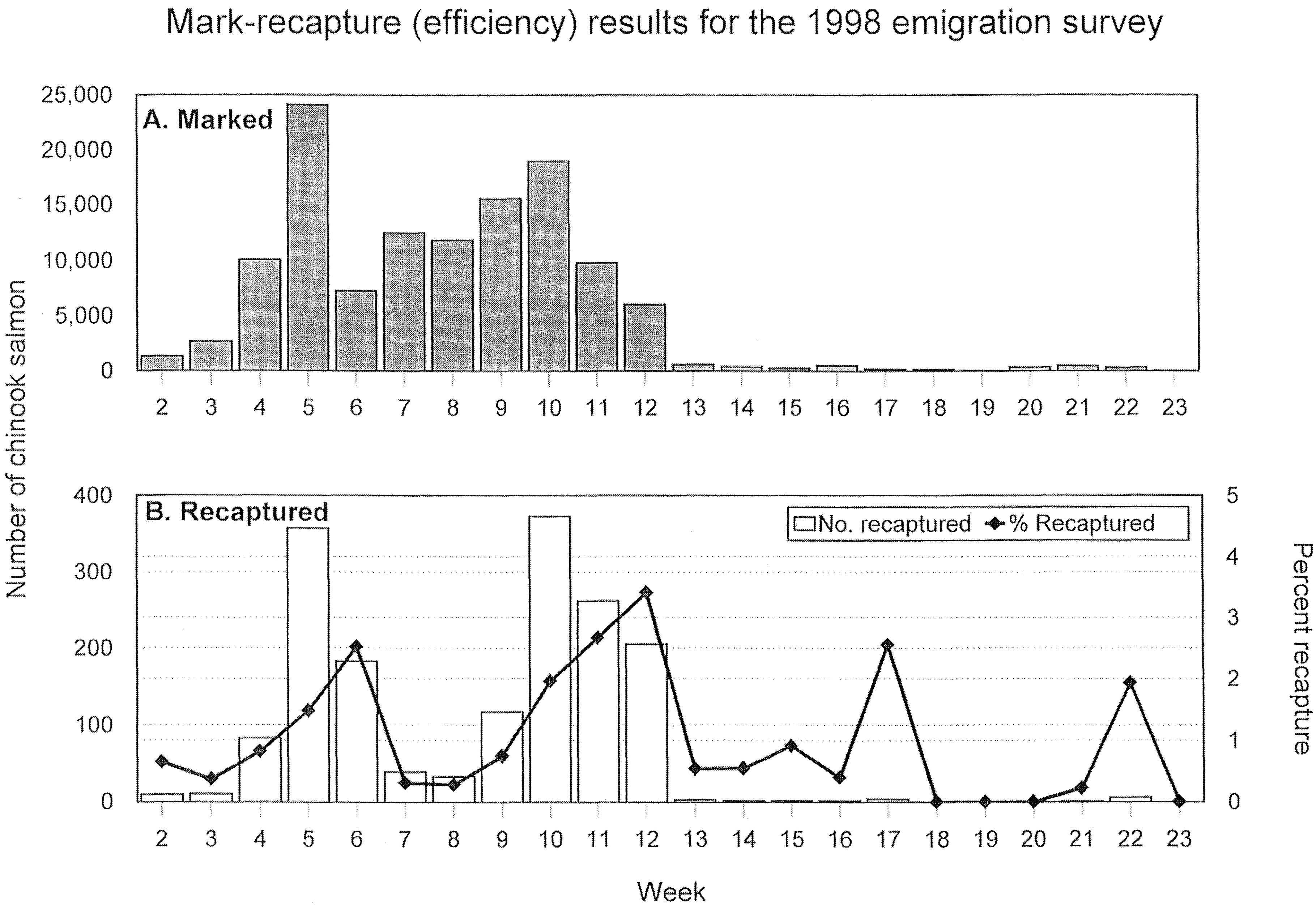

Figure 16. Number of chinook salmon marked (A) and recaptured (B) during the 1998 lower American River emigration survey, October 1997 through September 1998.

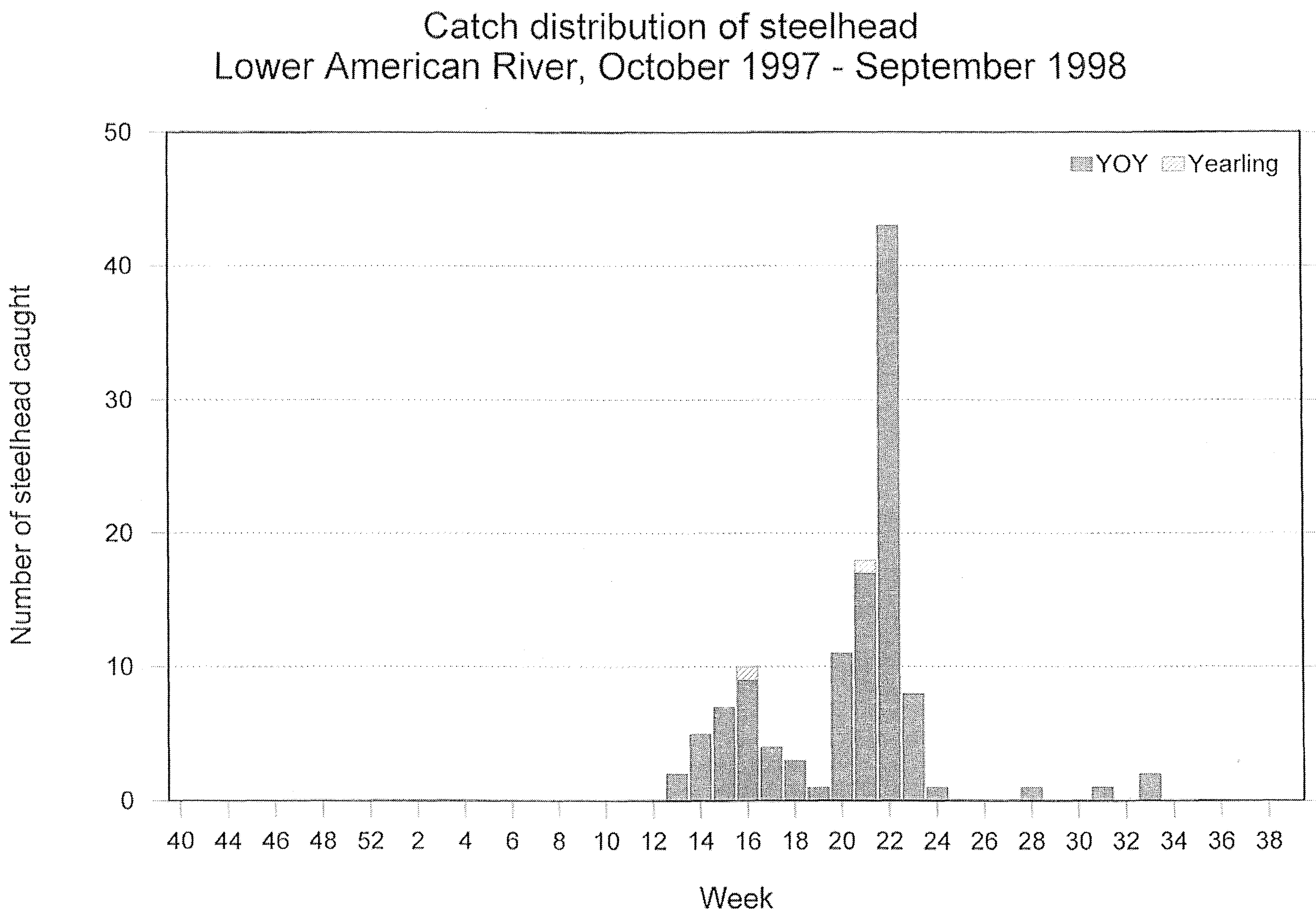

Figure 17. Catch distribution of young of the year (YOY) and yearling steelhead caught during the lower American River emigration survey, October 1997 through September 1998.

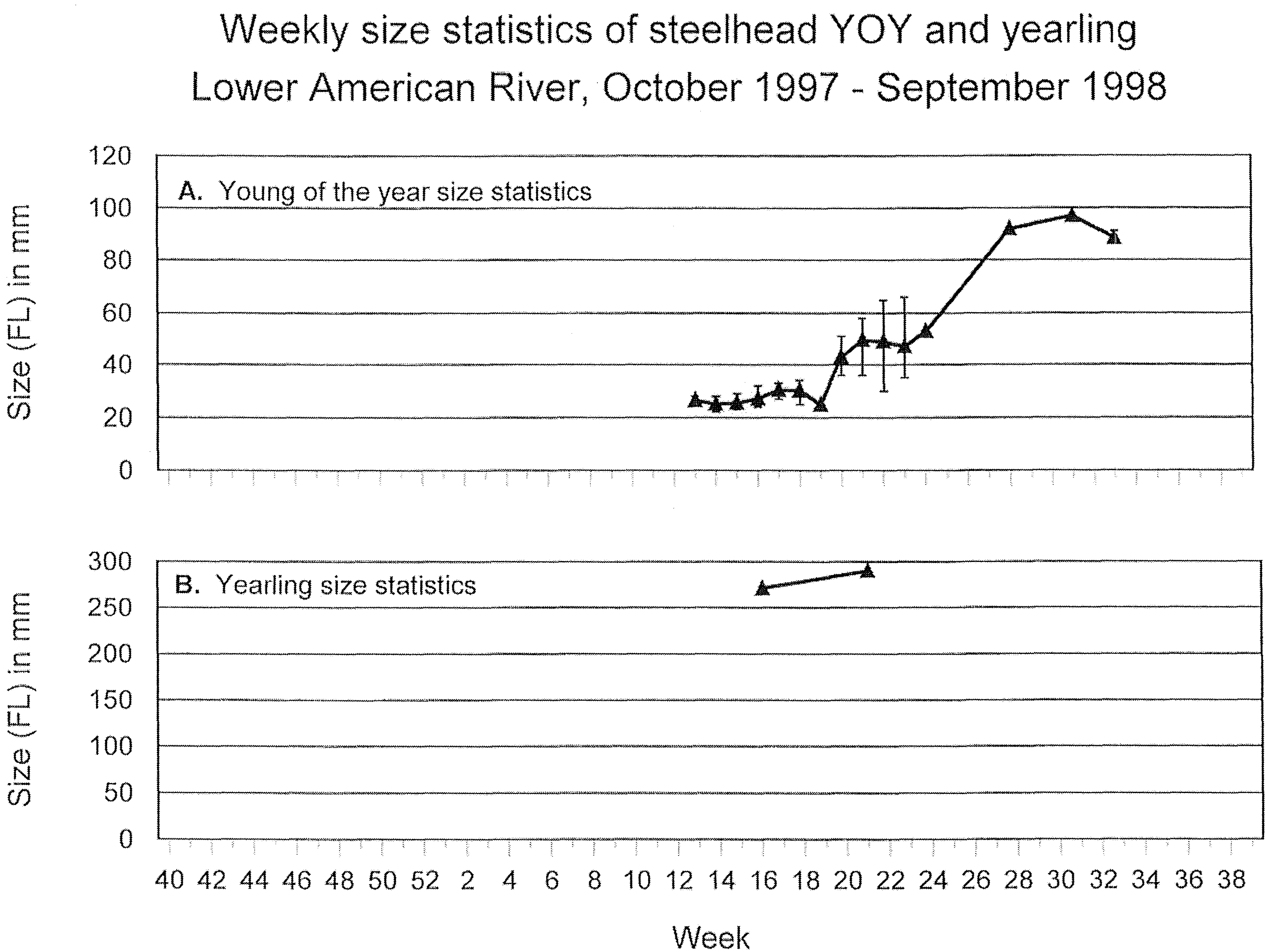

Figure 18. Mean fork length and size range of YOY (A) and yearling (B) steelhead caught by screw trap during the 1998 lower American River emigration survey, October 1997 through September 1998.